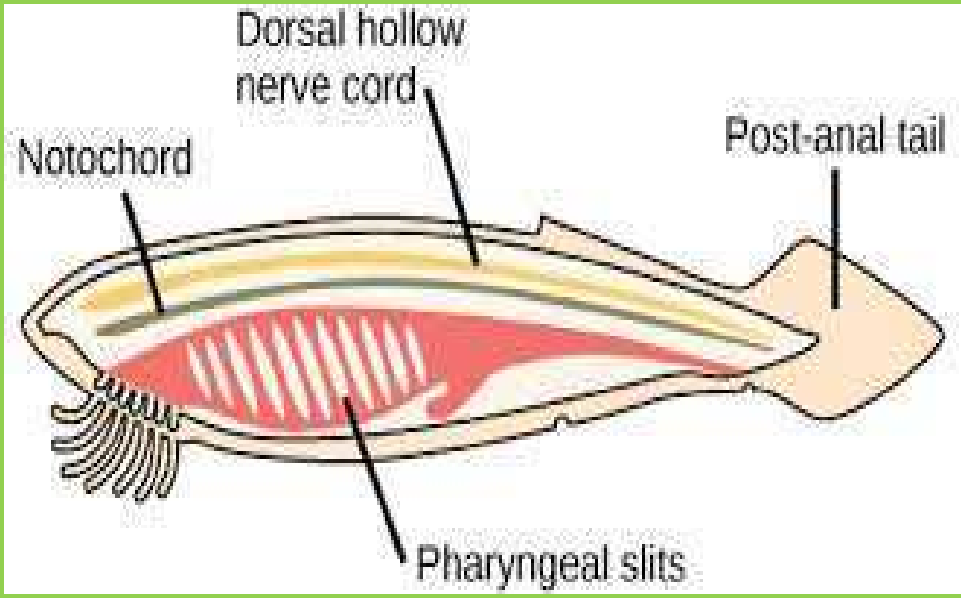
BSCZO- 201

B. Sc. II YEAR

CHORDATA



DEPARTMENT OF ZOOLOGY
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COURSE 1: CHORDATE
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UNIT 1: ORIGIN OF CHORDATES

CONTENTS

1.1 OBJECTIVE

We will understand the basic characters of chrodates, origin and Ancestrory of chordates.After reading this chapter we will also know about about the general characters and classification of chordates upto order level.

1.2 INTRODUCTION

Animal kingdom is basically divided into two sub kingdoms:

(a) Nonchordata- including animals without notochord.

(b) Chordata- This comprising animals having **notochord** or **chorda dorsalis**.While the Chordata has a **notochord** at some stage during the life, it is not known to exist in the Nonchordata.

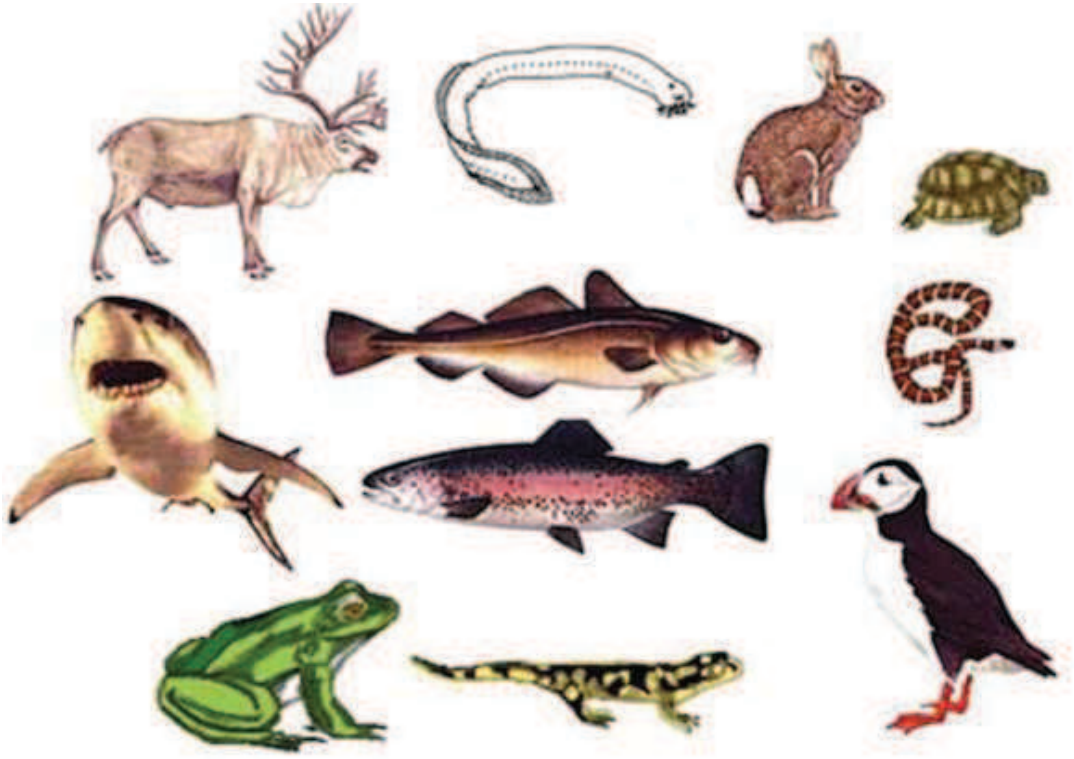


Fig.1.1 some animals of chordate phylum

- The Chordata is the animal phylum with which everyone is most intimately familiar, since it includes humans and other vertebrates However, not all chordates are vertebrates.

- All chordates have the following features at some stage in their life (in the case of humans and many other vertebrates, these features may only be present in the embryos).

- **Pharyngeal slits** – a series of openings that connect the inside of the throat to the outside of the "neck". These are often, but not always, used as gills.

- **Dorsal tubular nerve cord** – A bundle of nerve fibers which runs down the "back". It connects the brain with the lateral muscles and other organs.

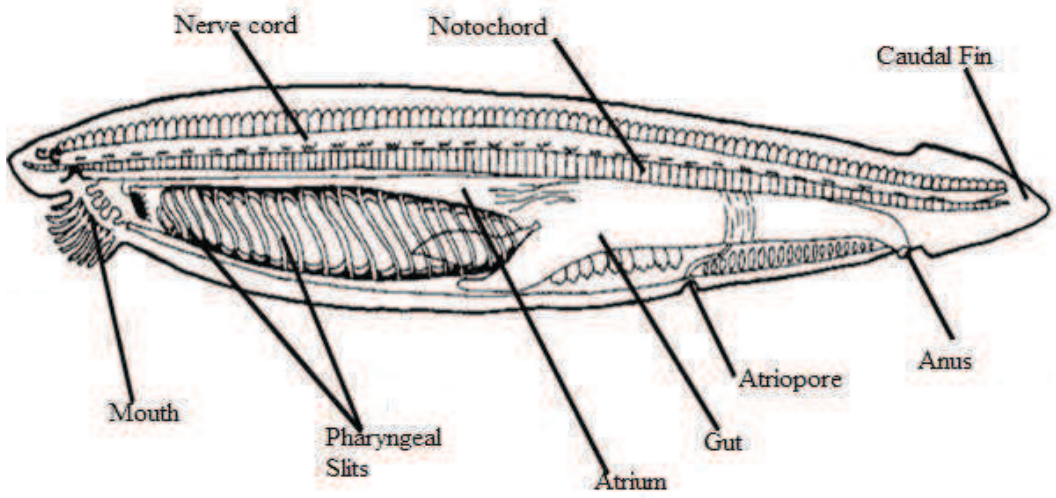


Fig 1.2 Pharyngeal slits dorsal nerve cord & notochord

- **Notochord** – cartilaginous rod running underneath, and supporting, the nerve cord.
- **Post-anal tail** – an extension of the body post the anal opening.

1.3 ORIGIN OF CHORDATES

It is believed that chordates originated from invertebrates. However, it is difficult to determine from which invertebrate group of the chordate developed. It is almost constant that chordate ancestors were soft bodied animals. Hence, they were not preserved as fossil.

Many theories have been put forward to explain the evolution of chordates, few of them are as follows:-

(a) COELENTERATE THEORY: According to this theory chordates developed from coelenterates. It is belived that radial symmetry coelenteron, cnidoblasts etc, disappeared and advanced characters developed to giverise the chordates. This theory infers that chordates might have acquired higher characters independently. This theory is not acceptable.

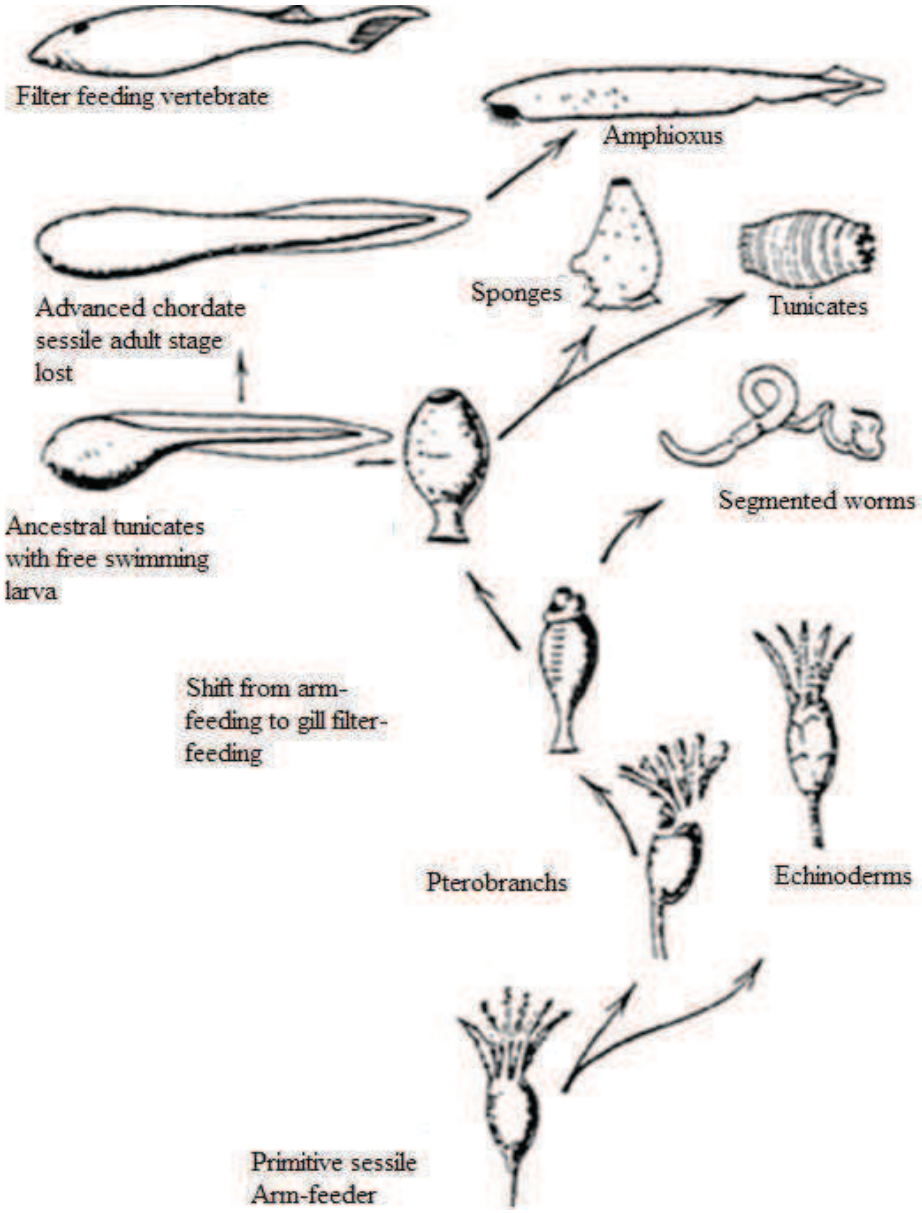


Fig.1.3 Origin of chordates

(b) ANNELID THEORY: This theory suggests that the chordates have evolved from an annelid stock, like many chordates the annelids show bilateral symmetry, metasmerism, head, lateral coelome complete digestive tract, closed circulatory system, haemoglobin, etc. The resemblance is enhanced, if an annelid is turned upside down. But the mouth would be dorsal which is unlike that of chordates. Metamerism and appendages of annelids differ in nature from those of the chordates. Bilateral symmetry, head and complete digestive tract occur in other non-chordate phyla also. Coelome is schizocoelic in annelids and enterocoelic in lower

chordates. Haemoglobin is dissolved in the plasma in annelids but it is present in the red blood corpuscles in chordates. Annelid nerve cord is double and ventral in contrast to single, hollow, dorsal nerve cord of chordates. Some striking differences exist between the annelids and the chordates in their embryology too, hence it is difficult to accept this theory.

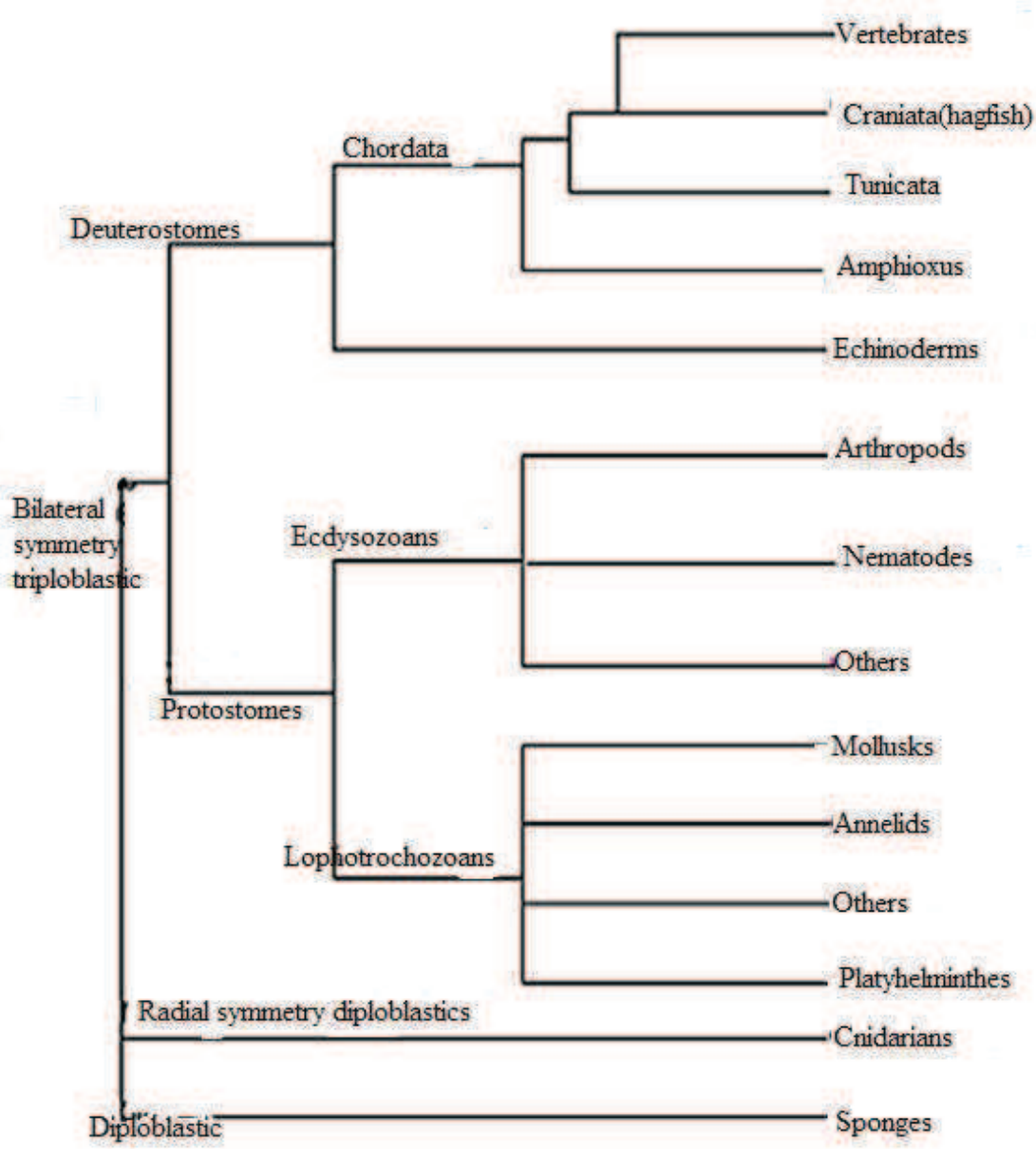
(c) ECHINODERM -HEMICHORDATE THEORY-ORIGIN OF CHORDATES: This theory infers origin of chordates, hemichordates and echinoderms from a common ancestor. This theory is based on the following evidences.

1. **EMBRYOLOGICAL EVIDENCE:** Both echinoderms and chordates have enterocoelic coelome, mesoderm and deuterostomous mouth. There is resemblance between the bipinnaria larva of certain echinoderms and the tornaria larva of hemichordates. In echinoderms chordates the central nervous system develops from a dorsal strip of ectoderm.

2. **SEROGICAL EVIDENCE:**
   Similarity exists between the protines of the body fluid of chordates and echinoderms. Hence the chordates and echinoderms are closely related. The radial symmetry of adult echinoderms will disapprove their relationship with the bilaterally symmetrical chordates. In echinoderms radial symmetry is secondryly developed from a basically bilateral symmetry. Both the primitive and the early echinoderm larve show bilateral symmetry.

1.4 ANCESTORY OF CHORDATES

The unique chordate body plan evolved within the deuterostome animals sometimes before the Cambrian (Valentine, Jablonski Erwin 1999; Blair and Hedges 2005). Chordates traditionally include vertebrates, lancelets (cephalochordates) and tunicates, but tunicates do not exhibit a chordate body plan as adults. Hemichordates are sister group to echinoderms and both phyla are an outgroup to the rest of the chordates).



X*enoturbella* has been recently included in the deuterostomes as molecular evidence unites them with hemichordates and echinoderms, but their exact position within the deuterostomes is not yet clear.m All five chordate characteristics (postanal tail, dorsal nerve cord, notochord, endostyle and pharyngeal gill slits) at one time or another been suggested to have homologous structures present in hemichordates, but all these features are lacking in echinoderms and *Xenoturbella*, the closest relatives to hemichordates, suggesting that they were lost during their evolution.

1.5 GENERAL CHARACTERSTICS

- Aquatic, aerial or terrestrial all free living with no fully parasitic forms.
- Bilaterally symmetrical and metamerically segmented.
- Exoskeleton often present well developed in most vertebrates.
- Bodywall triploblastic with 3 germinal layers: ectoderm, mesoderm and endoderm.
- Coelomate animals with a true coelom, enterocoelic or schizocoelic in origin.
- A skeletal rod, the notochord, present at some stage in life cycle.
- Digestive system complete with digestive glands.
- Blood vascular system closed. Heart ventral with dorsal and ventral blood vessels. Hepatic portal system well developed.
- Excretory system comprising proto –or meso-or meta-nephric kidneys.

1.6 CLASSIFICATION OF CHORDATES

PHYLUM CHORDATA

Group ACRANIA (=PROTOCHORDATA) (Primitive chordates without head and vertebral column)

Subphylum **HEMICHORDATA,** Example *Balanoglossus, Cephalodiscus, Rhabdopleura,* these are primitive and doubtful chordates; they are now classified under non-chordates after echinoderms.

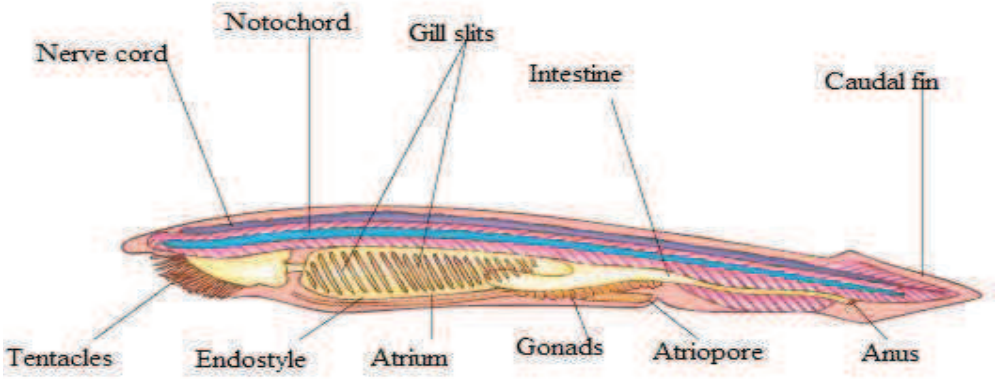


Fig.1.4 Primitive chordate character

Subphylum **UROCHORDATA,** Example- **Herdmania***, Salpa, Doliolum, Pyrosoma, Oikopleura.* These are *sedentary* or planktonic tunicates in which chordate characters manifest in the larval stage.

Subphylum **CEPHALOCHORDATA,** Example- **Amphioxus***, Asymmetron.* These are typical chordates having chordate characters in the larval as well as adult stages.

Group CRANIATA (=EUCHORDATA)

(Chordates with skull, with 54,000 species of true chordates)

Subphylum **VERTEBRATA,** chordates with head or skull, brain and vertebral column.

- Division **AGNATHA**, 90 species of paraphyletic group of jawless fishes, which were the first vertebrates. Living forms are elongated, scaleless, slimy parasites and scavengers that include lampreys and hagfishes. They have no paired fins.
- Class **OSTRACODERMI,** extinct shelled jawless fishes of Ordovician period. for Example- *Cephalaspsis.*
- Class **CYCLOSTOMATA,** jawless fishes of today, without scales and paired fins.
- Order **Myxinoidea**: the hagfish's containg 40 species. *Myxine, Bdellostoma, Eptatretus* are good examples.
- Order **Petromyzontia**: lampreys, 41 species, parasitic on other fishes. **For Example-** *Petromyzon.*
- Division **GNATHOSTOMATA,** vertebrates with jaws that are modified gill arches and paired appendages. They include cartilaginous fishes, bony fishes and tetrapods.

5. SUPER CLASS I: PISCES

Class PLACODERMI, extinct group of spiny sharks. for Example- *Climatius.*

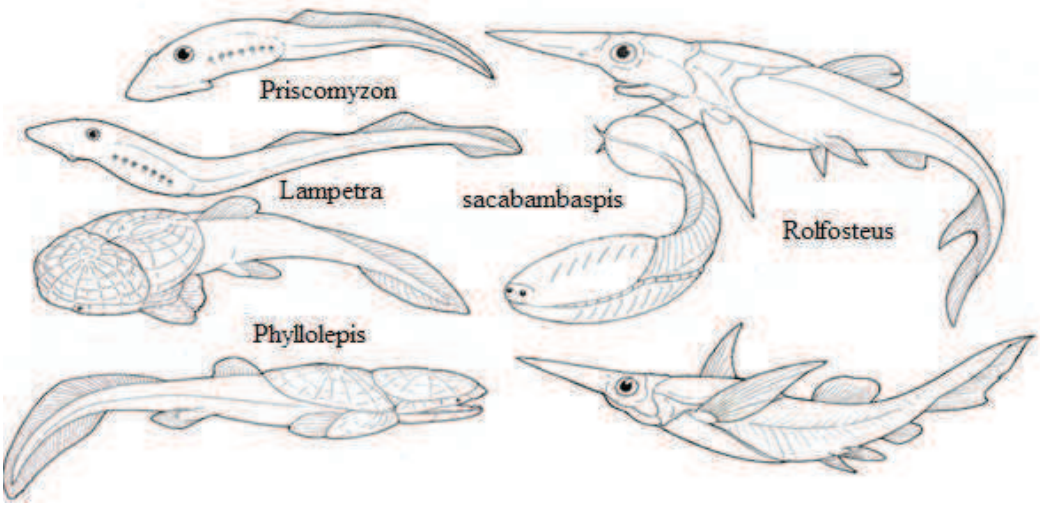


Fig.1.5Super class Pisces

Class **CHONDRICHTHYES:** cartilaginous fishes that have cartilaginous skeleton, ventral mouth, placoid scales, heterocercal tail fin and 5 pairs of gill slits.

- Subclass **Elasmobranchii**— 850 species of sharks, rays and skates.
- Subclass **Holocephali**— 30 species of ratfish *(Chimaeras)*.

Class **OSTEICHTHYES** 20,000 species, bony fishes. Skeleton bony, four pairs of gills, covered with operculum, possess swim bladder or lung.

- Subclass **Actinopterygii**, ray-finned fishes.
- Superorder **Chondrostei**, 25 species of sturgeons, bichirs and paddlefish.
- Superorder **Holostei**, which includes *Lepistosteus (*7 species) and *Amia (*1 species)
- Superorder **Teleostei,** includes 20,000 species of bony fishes, such as tarpon, herring, perch, etc.
- Subclass **Crossopterygii,** includes 2 species of coelacanth *(Latimeria).*

Class **CHOANICHTHYS (=DIPNOI)**, has 6 species of lungfishes under three genera, namely, *Protopterus, Lepidosiren* and *Neoceratodus.*

6. SUPERCLASS CTETRAPODA: Two pairs of paired appendages

Class **AMPHIBIA**

- Order **Gymnophiona** (Apoda) —165 species of burrowing caecilians, elongated bodies, and limbless, dermal scales embedded in annular folds of skin.
- Order **Caudata** (Urodela) —425 species of salamanders, tailed amphibians, usually with two pairs of limbs.
- Order **Anura** (Salientia) —4300 species of frogs and toads, tail-less amphibians, long hind limbs for jumping, head and trunk fused. They have sound producing and hearing organs.

Class **REPTILIA,** 7800 species, turtles, crocodiles, lizards, snakes, etc.These are the tru land vertebrates and never come return breeding in water.

They have internal fertilization and produce large cleiod eggs with leathery shells and are ectotherms. Bodies covered with epidermal scales and vertebrae are procoelous.

- Order **Chelonia**, 300 species of turtles and tortoises having bony shell on the body.
- Superorder **Lepidosauria,** lizard-like with acrodont or pleurodont dentition.
- Order **Rhynchocephalia (=Sphenodontia**), 2 species of tuatara *(Sphenodon)* in New Zealand. They have acrodont teeth, amphicoelous vertebrae and a parietal eye.
- Order **Squamata,** with pleurodont teeth, procoelous vertebrae, without third eye.
- Suborder **Lacertilia** includes 4000 species of lizards.
- Suborder **Ophidia** includes 2700 species of snakes.
- Superorder **Archosauria** includes modern crocodiles and extinct dinosaurs.
- Order **Crocodilia**, 23 species of alligators, crocodiles and gavials

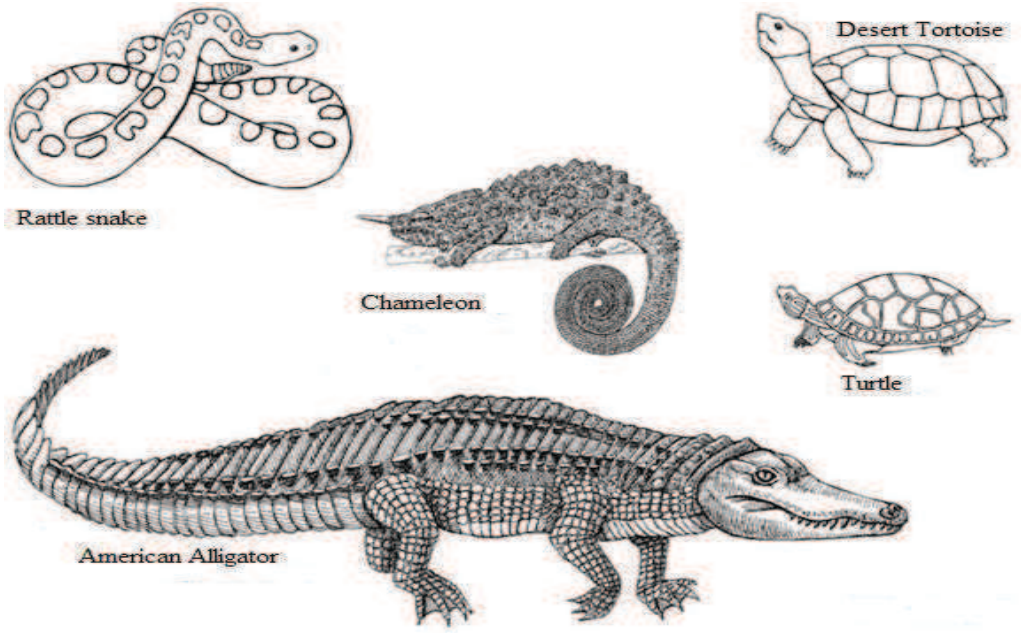


Fig.1.6 Different types of Reptiles

Class **AVES,** 9100 species.

Birds being feathered bipeds have internal fertilization and lay hard-shelled eggs and are endotherms. Nearly every anatomical feature is related to ability to fly. They are the only animals with feathers that are modified from reptilian scales.

Class **MAMMALIA,** 4,500 species.

Mammals evolved in the late Triassic, the time dinosaurs first appeared and diversified greatly following the extinction of dinosaurs during the Coenozoic. Characteristics include hairs for protection and from heat loss; mammary glands; heterodont teeth; endothermy; 4 chambered hearts etc.

- Subclass **PROTOTHERIA, Order Monotremata,** egg laying mammals having 6 species in Australia and New Zealand. No teeth and true mammary glands.
- Subclass **METATHERIA, Order Marsupialia,** 275 species of marsupials that have brief gestation period after which the embryo develops in a pouch. They have prolonged lactation and parental care. Marsupials include: opossum, kangaroo, koala, Tasmanian devil, wombat, etc.

- Subclass **EUTHERIA**, **16 orders** which include 4700 species of placental mammals that are truly viviparous, with a placenta for gas and nutrient exchange between the mother and foetus. They also have true mammary glands.

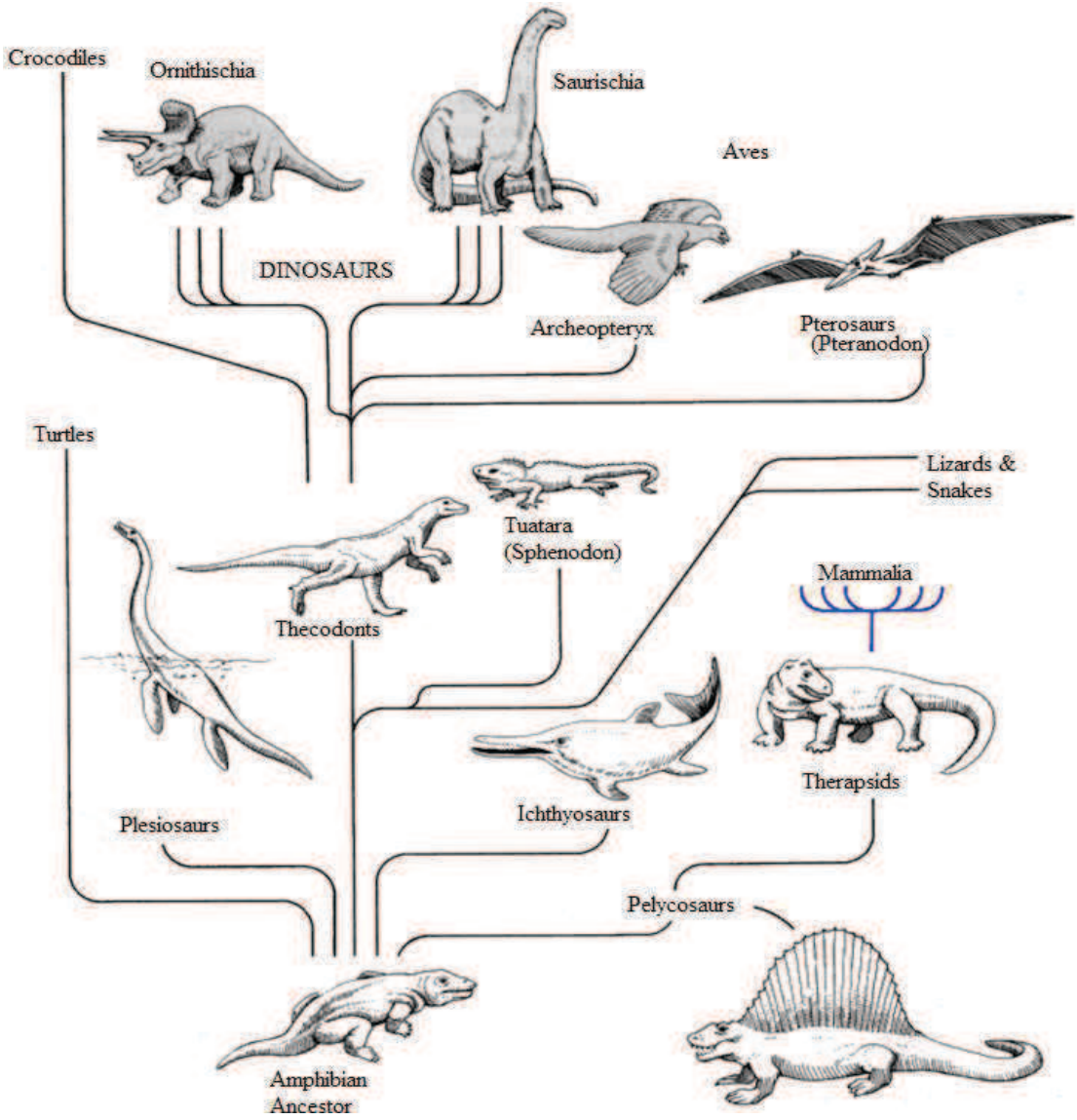


Fig.1.7 Different class of chordate

1.7 SUMMARY

The chordates are of various body forms but they all have notochord, dorsal tubular nerve cord, pharyngeal slits and a post anal tail at some stage of life .Various theories have been proposed to explain the origin and evolution of chordates but none of them is completely satisfactory, However, it is belived that they evolve sometimes before Cambrians.The most advanced forms of chordates are mammals.

1.8 GIOSSARY

Cephalochordata

Group of Chordate clade whose members possess a notochord, dorsal hollow nerve cord, pharyngeal slits, and a post-anal tail in the adult stage besides, they possess ciphalon i.e head.

Chordata

Phylum of animals distinguished by their possession of a notochord, a dorsal tubular nerve cord, pharyngeal slits, and a post-anal tail at some point during their development

Craniata

Clade composed of chordates that possess a cranium; includes Vertebrata together with hagfishes

Cranium

Bony, cartilaginous, or fibrous structure surrounding the brain, jaw, and facial bones

Dorsal hollow nerve cord

Hollow, tubular structure derived from ectoderm and is located dorsal to the notochord in chordates

Lancelet

Member of Cephalochordata; named for its blade-like shape.

Notochord

Flexible, rod-shaped support structure that is found in the embryonic stage of all chordates and in the adult stage of some chordates

Pharyngeal slit

Opening in the pharynx

Post-anal tail

Muscular, posterior elongation of the body extending beyond the anus in chordates

Tetrapod

Phylogenetic reference to an organism with a four-footed evolutionary history; includes amphibians, reptiles, birds, and mammals

Tunicate

Sessile chordate that is a member of Urochordata

Urochordata

Clade composed of tunicates

Vertebral column

Series of separate bones joined together as a backbone

Vertebrata

Members of the phylum Chordata that possess a backbone.

1.9 SELF-ASSESSMENT QUESTIONS

1. Which of the following is the Class of the Jawless Fish?

A. Chondrichthyes

B. Chordata

C. Osteichthyes

D. Agnatha

2 Which of the following is not a feature of the Class Agnatha?

A. External Fertilliation

B. Ectothermic

C.No Paired Limbs

D.Has scales

3. Notochord is confined to proboscis in:

A. Urochordata

B. Hemichordata

C. Cephalochordata

D. Chordata

4. Chondrichthyes have a.....

A. Closed circulatory system

B. 3 chambered heart

C. Clitellum

D. Radial symentry

E. All of the above

5. An example of an animal from the Class Agnatha is a...
   A. Red Trailed Fox
   B. Humanoid
   C. Rock Bass
   D. Lamprey

6. Which of the following is not an example of an animal from the Class Chondrichthyes?
   A. Ray
   B. Skate
   C. Sea Urchin
   D. Shark

7. What would a rainbow trout be an example of?
   A. Osteichthyes
   B. Agnatha
   C. Fishinidia
   D. Troutlopod
   E. None of The Above

8. Which class would a frog belong to?
   A. Frogania
   B. Amphibian
   C. Agnatha
   D. Animmalia

9 Dry scaly skin, ectothermic, 2 Paris of legs, lungs, internal fertilization, leathery eggs with amniotic shell, and a 3.5 chambered heart are all properties of the class?
   A. Osteichthyes
   B. Agnatha
   C. Amphibian
   D. Reptiles

Answers

1.(D) 2.(E) 3.(B) 4.(A) 5 (D) 6. (C) 7.(A) 8.(B) 9.(D) .

1.10 TERMINAL QUESTION ANSWERS

1. Give the classification of Chordata.

2. Give the gearenal characters of the phylum chordate.

3. Describe the diagnostic characters of the phylum chordate and point out the main differences from that of nonchordate?

4. Classify phylum Chordata upto classes giving the important characters and examples of each class?

1.11 SUGGESTED READING

1. Nigam, H.C.1983.Zoology of chordates, Vishal publication, Jalandhar.
2. Kotpal, R.L 2012.Vertebrata, Rastogi publication Merruth.

1.12 REFERENCES

1. Jordan E.L. and P.S. Verma 1995.Chordate Zoology and Elements of Animal Physiology.S.Chand and Co.New Delhi
2. Kotpal, R.L 2012.Vertebrata, Rastogi publication Merruth.
3. Nigam,H.C.1983.Zoology of chordates,Vishal publication,Jalandhar
4. Some figure and tax material are adopted from Wikipedia.
5. Some figure and tax material are adopted from Biozoomer.

UNIT 02: HEMICHORDATA

CONTENTS

2.1 OBJECTIVE

To understand the general characters of Himichordata and the classification upto order level of Himichordata.We will also study a type specimen of Hemichordata (Balanoglossus) and its affinities & the ecological terms.

2.2 INTRODUCTION

Not familiar creatures to most people, hemichordates form a small phylum (only a few hundred species). Their importance for the study of vertebrate evolution, however, cannot be underestimated. The fossil record of one group of hemichordates, the graptolites, is very well known and is often used to correlate rocks.

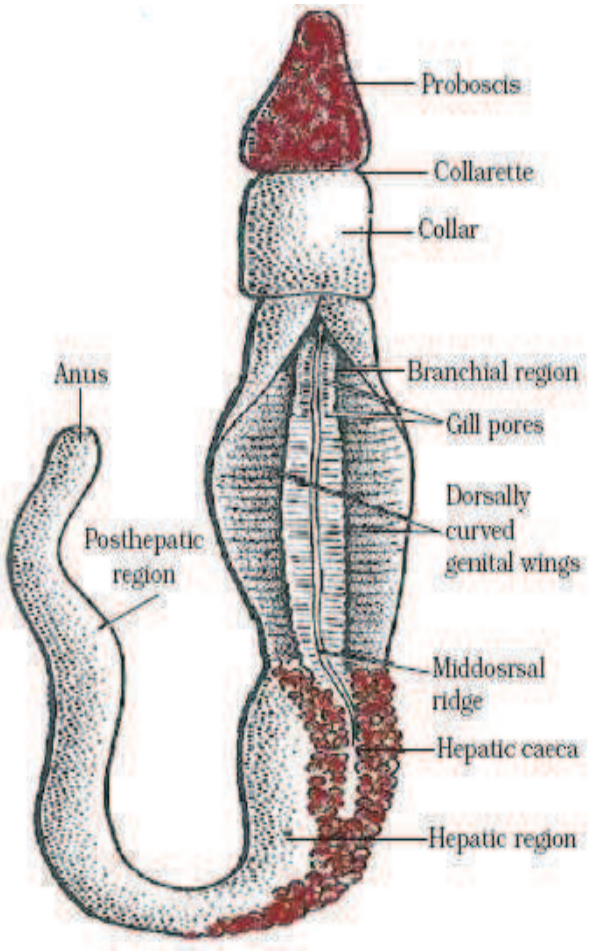


Fig.2.1 Balanoglossus (External Feature)

Hemichordata (Gr.hemi-half ;chorde-cord) till recently treated as a subphylum of the phylum Chordata is now regarded as an independent phylum of invertebrates, close to Echinodermata, Hemichordata or Acelochordata are tongue worms .It includes a small group of soft, vermiform, marine and primitive chordates, most of them live in tubes. Hemichordates are distinguished by a **tripartite** (threefold) division of the body. At the forward end of the body is a **preoral lobe**, behind this is a collar, and in the posterior side there is the word “hemichordate" means "half chordate,". They share some (but not all) of the typical chordate characteristics.

The body and enterocoelous coelom are divided into three unequal regions: Proboscis, collar and trunk.

Acorn worms also have multiple branchial openings, as many as 200 in some species. They are slow burrowers like earthworm, using the proboscis to burrow through sediment.They may either be **deposit feeders** (consume sediment and digest the organic matter like earthworms in soil) or **suspension feed**ers (collect suspended particles from the water). Some of these worms may be very large; one species may reach a length of 2.5 m (almost eight feet), although most of them much smaller.Development is direct in some, while is found in a tornaria larva.

Hemichordates are dioecious (i.e., males and females, although they cannot be distinguished externally) with external fertilization and are development is indirect (i.e., there is a distinct larval form). Asexual reproduction occurs in at least some acorn worms and in most pterobranchs. Acorn worms fragment small pieces from the trunk, each of which can then grow into a new individual. Pterobranch colonies are derived by budding of a single sexually produced individual. Sexual reproduction in pterobranchs produces non-feeding larvae that are brooded in the colony. (Brusca and Brusca 2003; Cannon et al. 2009).

2. 3 GENERAL CHARACTERS AND CLASSIFICATION

2.3.1 GENERAL CHARACTERS OF HIMICHORDATA

- Bilaterally symmetrical and exclusively marine, worm- like and soft bodied animals.
- Body cavity a true coelom (enterocoel).

- Body divided into three sections, Proboscis, collar and trunk. Numerous paired gill-slits are present.
- Digestive tube complete, straight or U-shaped.
- Nervous system normally diffuses, but variable and partially open circulatory system.
- Possesses Glomerulus as an excretory organ and reproduction normally sexual, sexes usually separate but few acorn worms also exhibit asexual reproduction.
- Fertilization external in sea water .Development direct or indirect with a free swimming tornaria larva. Feeds on fine particles in the water.

  Etymology: - From the Greek Hemi for half and the Latin Chorda a chord

2.3.2 CLASSIFICATION UP TO ORDER LEVEL

Phyllum Hemichordata is divided into following four classes:

Class **1** **Enteropneusta**

(Gr.enteron, gut + pneustos, breathed).

- They are solitary, free swimming or burrowing animals and are commonly called as 'acron or tongue worm.
- They are worm like and bear many pharyngeal gill- slits.
- They possess straight alimentary canal.
- Development includes tornaria larva in some.
- They lack asexual reproduction.

Examples: Balanoglossus, Spengelia, Protoglossus, Saccoglossus etc.

Class **2 - Pterobranchia**

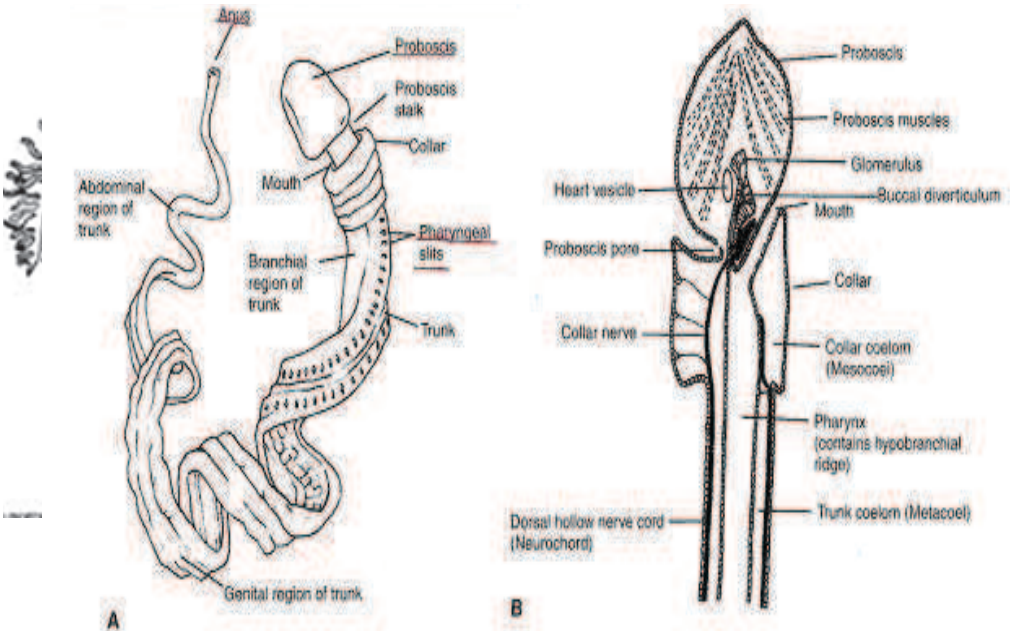


Fig.2.2 A: Spengilia B: Protoglossus

(Gr. Pteron, feather + branchion gill)

- These are sessile animals, Alimentary canal U-shaped with dorsal anus.
- Proboscis shield –like and gill slits one pair or absent
- Asexual Reproduction by budding(Sexes are separate ,one pair gonads)

Order 1 - Rhabdopleurida

- Colonial form.
- Collar with two tentaculated arms.
- Single gonad is present.
- Gill slits absent.

- **Ex - Rhobdopleura**

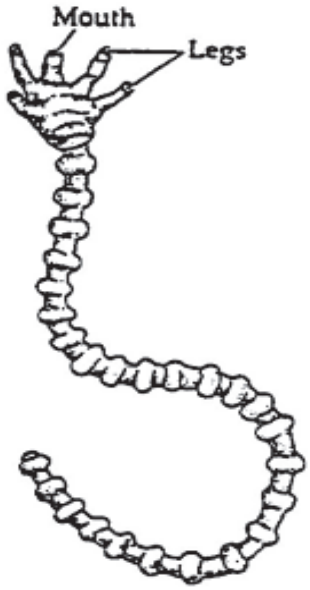


Fig.2.3 Rhabdopleurida, A single zooids

Order 2 - Cephalodiscida

- Solitary or many zooids living in a common gelatinous house.
- Two gill slits present.
- Gonad single pair.

Example. Cephalodiscus

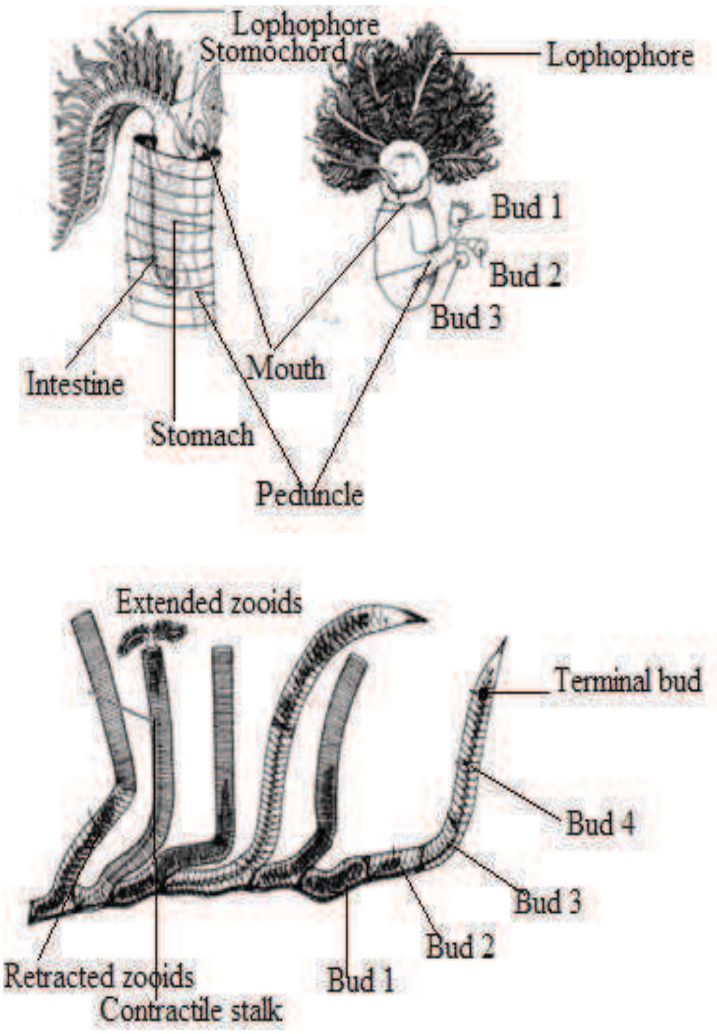


Fig.2.4 Cephalodiscus

Class 3 - Planctosphairoidea

- These are known only by a round transparent pelgie larva related to tornaria larva.
- The alimentary canal of larva is U –shaped.

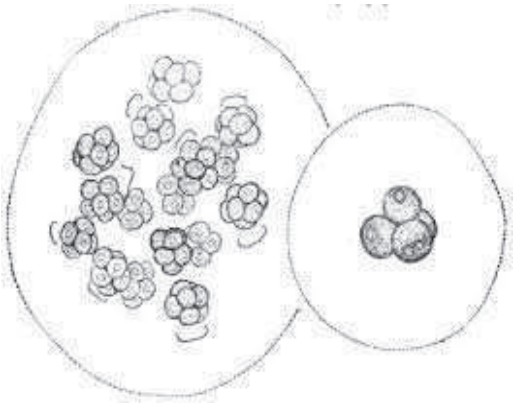


Fig 2.5 Planctosphairoidea

Class 4 - Graptalita

- These are fossils.
- These are extinct colonial hemichordates.
- Their tubular chitinous skeleton and colonial habits show an affinity with Rhobdopleura

2.4 TYPE STUDY AND AFFINITY

2.4.1 GENERAL STUDY OF BALANOGLOSSUS (TONGUE WORM)

Systematic Position

Phylum	Chordata
Subphylum	Hemichordata
Class	Entreopneusta
Family	Ptychoderidae
Type	Balanoglossus

(a) Habit And Habitat

Balanoglossus is a marine, tubicolous or burrowing hemichordate inhabiting shallow coastal waters of intertidal zone, but a few occur in deeper water. Clavigerus lives inside a U-shaped tube or burrow with the two vertical limbs 50-75 cm deep and two opening 10-30 cm apart .The anterior opening of burrow is funnel shaped and posterior end is rounded and concealed below the spirally coiled faecal matter of the animal.

Balanoglossus is an ocean-dwelling **acorn worm** (Enteropneusta) **genus** of great **zoological** interest because, being a **Hemichordate**, it is an "evolutionary link" between **invertebrates** and **vertebrates**. *Balanoglossus* is a **deuterostome**, and resembles the **Ascidians** or **sea squirts**, in that it possesses **branchial openings**, or "**gill slits**".It has notochord in the upper part of the body and has no nerve chord. It does have a **stomochord**,

however, which is gut chord within the collar. Their heads may be as small as 2.5 mm (1/10 in) or as large as 5 mm (1/5 in).

(b) External Features:

Balanoglossus is worm-like animal with soft, elongated cylindrical body. They range in length from 3 cm to as much as 2.5 m (*B. gigas*). They are bilaterally symmetrical animals.The body surface is uniformly ciliated and is uniformly covered with mucus. The body is divided into three parts: (1) proboscis (protosome, (2) collar (mesosome), and (3) trunk (metasome).

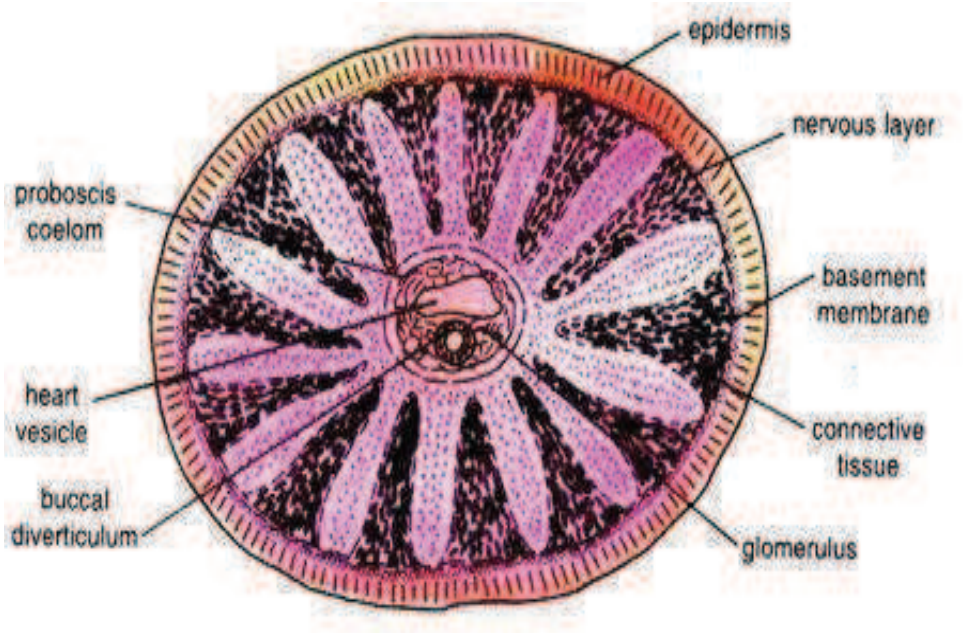


Fig.2.6 T.S of Balanoglossus through proboscis

(c) Proboscis

It is the anterior-most part of the body and is conical in form, tapering anteriorly. Posteriorly, it continues into a narrow proboscis stalk which is mostly concealed under the collar and is continuous with the inner surface of the dorsal wall of collar. Below the stalk base the proboscis bears a "U" shaped cilialed depression called the preoral ciliary organ which is a chaemoreceptor. Proboscis encloses coelom of proboscis.Which opens out through the proboscis pore situated mid-dorsally near its base.

(d) Collar

It is middle, short and thick belt-like pan of body, lying behind the proboscis. Its surface is often marked with circular grooves or elevations. The anterior funnel-like part of collar that encircles the proboscis stalk is called collarette. Vcntrally, below the proboscis stalk, the collarette encloses a wide aperture, the mouth. The collar is well demarcated from the trunk behind by a circular constriction. The collar has thick musculature and encloses the collar coelom. Sometimes the collar coelom is divided into left and right parts by dorsal and ventral mesenteries. The collar coelom opens by a pair of collar pores into the first pair of branchial sacs.

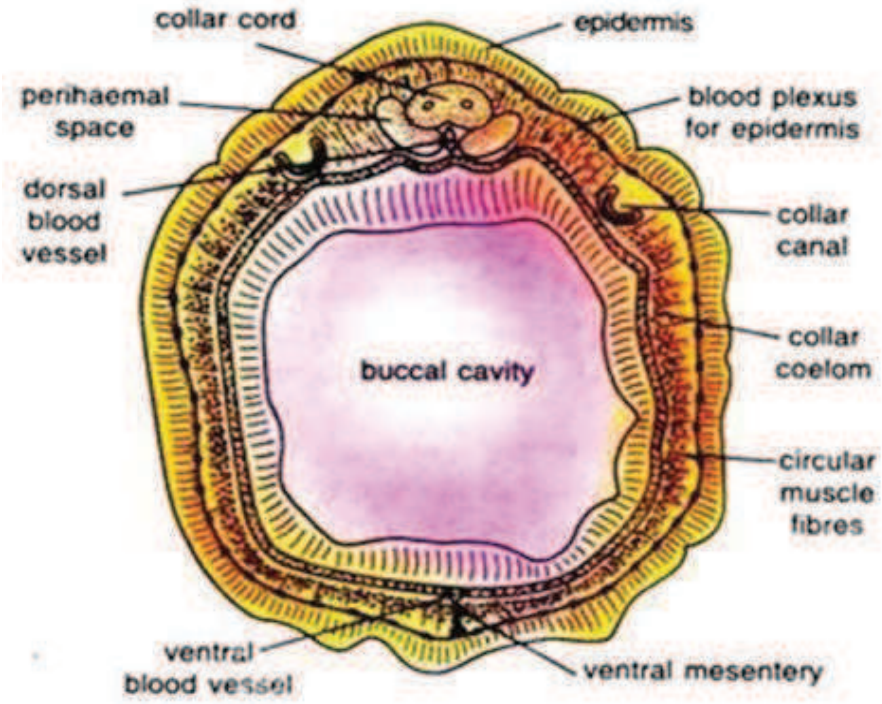


Fig.2.7 T.S of Balanoglossus through collar

(e) Trunk

It is the posterior and largest part of the body. It is somewhat flattened and usually shows superficial annulations. It is also marked by mid-dorsal and mid-ventral longitudinal ridges and is differentiated into three regions: the anterior branchio-genital region, middle hepatic region and posterior abdominal region, The branchio-genital region is distinguished by the presence of a longitudinal row of gill- pores on either side of mid-dorsal ridge. Each row of gill- pores is mounted on a prominant ridge-like elevation. The sides of branchio-genital region are thin and

leaf-like and are referred to as genital wings, containing the gonads. The gonads open out through gonopores which are microscopic apertures. The genital wings are usually curved and folded as the dorsal side coming close together in the median line thereby concealing the gill-pores.

Branchiogenital region –the anterior or branchiogenital region of trunk is marked by a pair of lateral, thin, flat and longitudinal flaps, the genital wings, which contains the gonads.

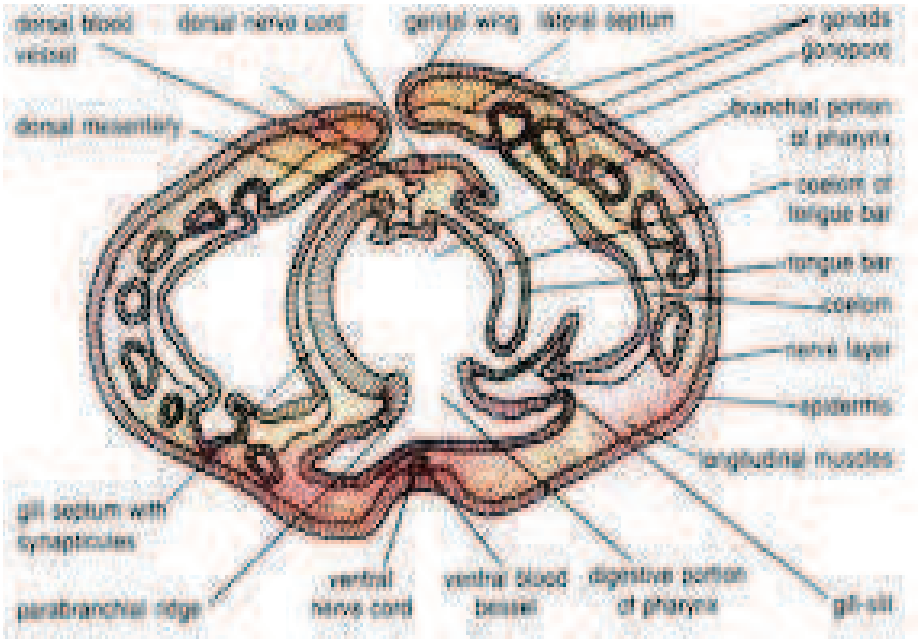


Fig.2.8 T.S of Balanoglossus through Brachiogenital region

(f) Hepatic Region

The hepatic region is marked by numerous small, paired, transverse folds, the hepatic caeca, on the dorsal side. It is dark brownish or greenish in colour. The post-hepatic region or abdominal region gradually tapers behind and bears a terminal anus. The posthepatic region-it is the posterior most and the longest part of the trunk and is also called the abdomen or the caudal region.

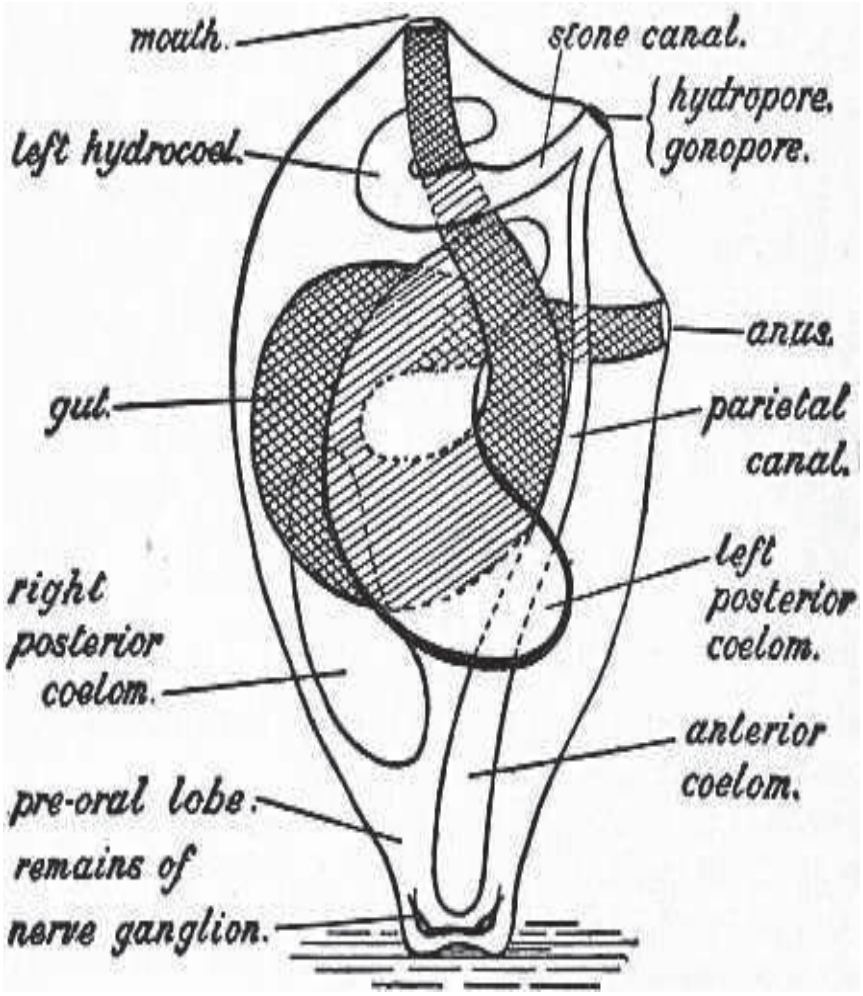


Fig 2.9 Hepatic region

(g) Body wall.

The body wall is composed of epidermis, musculature and peritoneum. Epidermis is outermost layer or and consists of a single layer of mostly tall, slender, columnar and ciliated cells. Dermis is absent. The muscles are smooth, weak and mostly longitudinal.In the trunk region, only longitudinal muscle fibres is present.

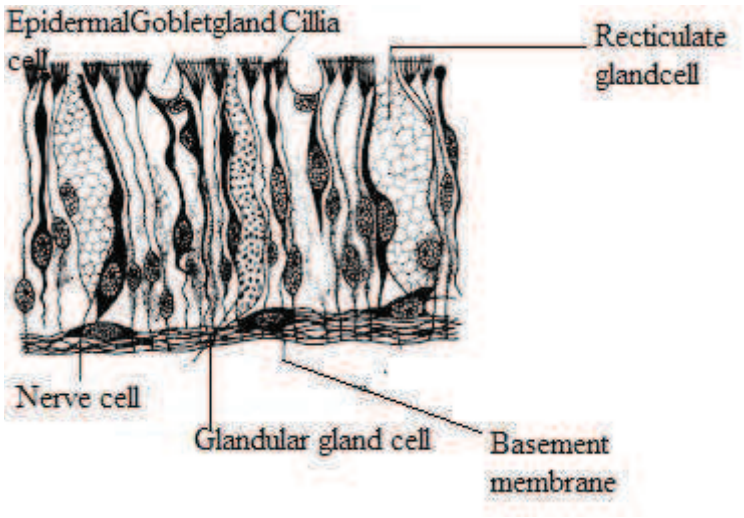


Fig.2.10 Balanoglossus V.S of body wall

The coelom is lined by the parietal coelomic epithelium or peritoneum which covers the inner surface of the body wall musculature.

(h) Coelom

Early developmental stages of *Balanoglossus* possess a spacious coelom lined with peritoneum. It is enterocoelous in origin. As the adult condition is attained, the coelomic epithelium gives rise to the connective tissue and muscle fibres. Hence the coelomic cavity is obliterated. The coelom as a whole is divided into three parts.

(i) Proboscic coelom (Protocoel)

In the proboscis, the coelom is a small, unpaired cavity into which several structures like buccal diverticulum, central sinus, heart vesicle, glomerulus etc. project from the base of the proboscis. The proboscis coelom opens out through a dorsal pore at the base of proboscis.

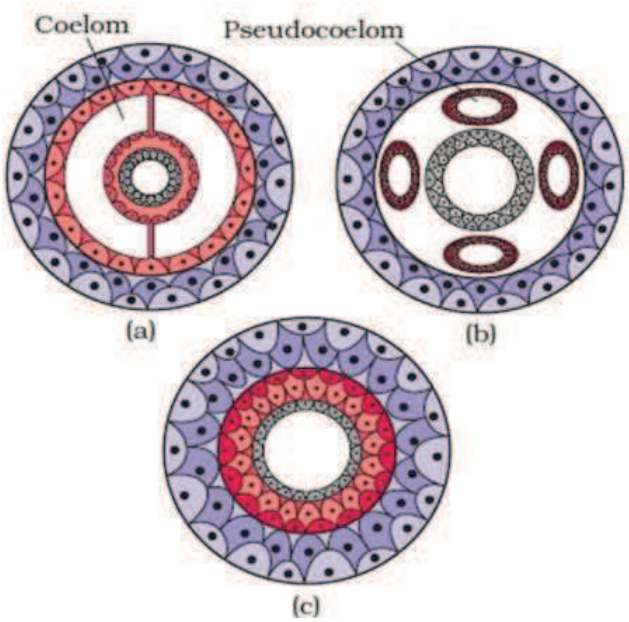


Fig.2.11 Balanoglossus: Diagramatic representation of coelome

(ii) Collar coelom (Mesococl)

In the collar, the coelom consists of two separate sac-like cavities on left and right side due to the presence of dorsal and ventral mesenteries. They communicate with the first pair of gill- sac by a pair of collar pores.

(iii) Trunk coelom (Metacoel)

In the trunk the coelom consists of a pair of cavities which are separated by incomplete mid-dorsal and complete ventral mesenteries. The trunk coelom is filled with coelomic fluid containing amoeboid corpuscles, the coelomocytes. They originated from coelomic epithelium. According to Spengel (1893), the coelomocytes secrete a membrane around any foreign particle which invades the animal thus behaving like leucocytes.

(i) Endoskeleton

A definite endoskeletal system is absent in *Balanoglossus*but the basement membrane becomes extraordinary thickened and lamellated to perform the function of skeleton. Following are the skeletal elements:

(i) Buccal diverticulum

It is short, hollow and stiff tube-like projection extending forward through the proboscis stalk into the proboscis coelom. Bateson (1885) referred it as alleged notochord. While

Willy (1899) and Dawydoff 1948) termed it as stomochord. Hyman preferred to call it as the buccal diverticulum. Its wall is composed of a

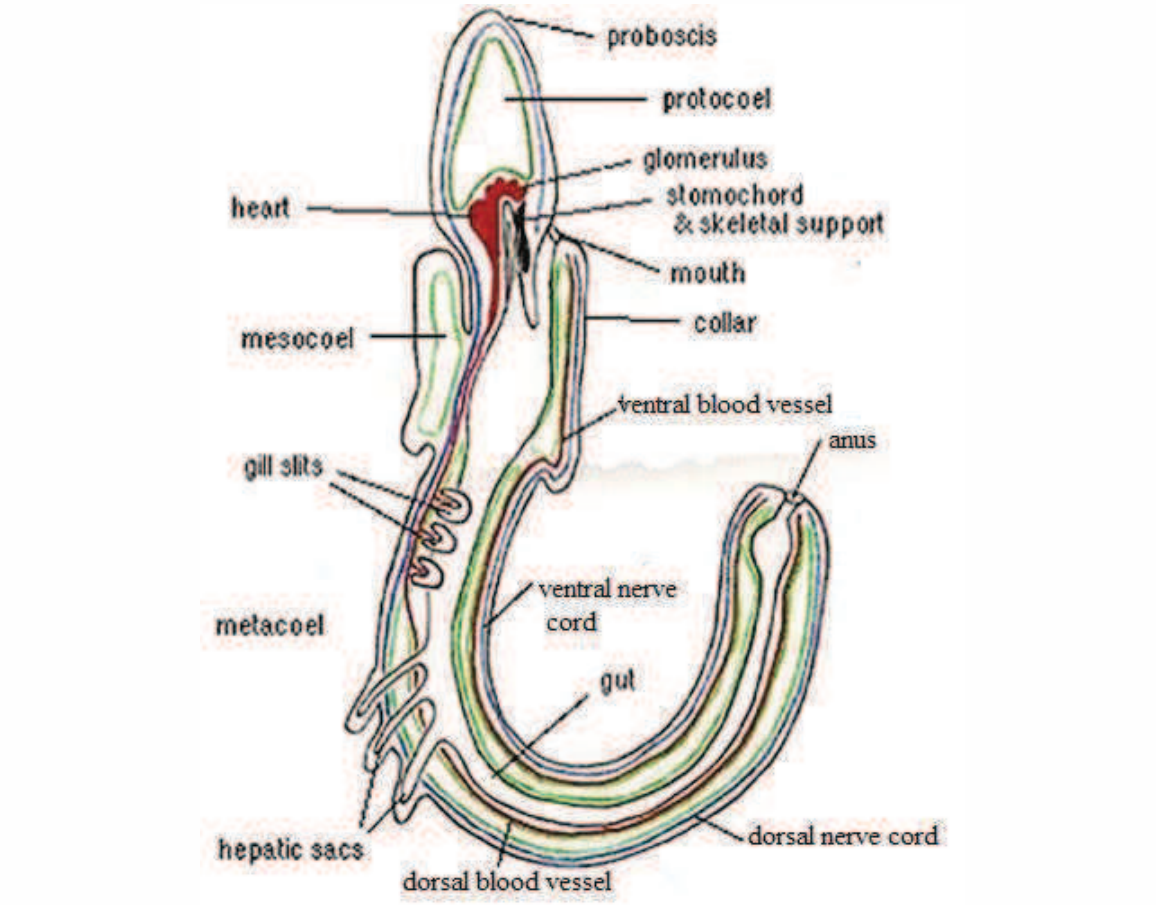


Fig.2.12 Endoskeleton of balanoglossus

single layer of tall, slender, vacuolated endodermal cells. Silen (1950) has assumed it as an extension of the preoral-region of the digestive tract.

(ii) Proboscis skeleton

It is a' Y' shaped structure, partly secreted by the epithelium and partly by coelomic tissue. It resembles to a hyoid apparatus in general appearance. It consists of a median plate in the proboscis stalk and continues behind into two narrow horns which extend into the roof of buccal cavity.The median plate is produced ventrallv into keel. The median plate lies below the buccal diverticulum.

(iii) Branchial skeleton

It is formed by the thickening of the basement membrane. it consists of numerous M – shaped chitinous skeletal rods that lie in the wall of the pharynx and support the U-shaped gill –slits that perforate it

(j) Pygochord

In the post- hepatic region of the trunk, mid-ventrally between the intestine and body wall, developes a rod-like thickening called phygochord.Its cells are vacuolated.

(k) Digestive system

It consists of the following parts:-

(i) Mouth:

At the base of proboscis stalk a wide circular opening, mouth is situated ventrally and is covered by collarette.It has two sets of muscle fibers, the radial fibers to open it and the concentric fibers to close it. Mouth leads into buccal cavity.

(ii) Buccal cavity:

It lies in collar region and its epithelial wall contains glandular goblat cells. Anteriorly it forms hollow buccal diverticulum and posteriorly extends up to the collar trunk septum and leads into the pharynx.

(iii) Pharynx:

It lies in the branchial region of the trunk. Its wall has lateral constrictions projecting into its lumen as ridges called parabranchial ridges.These ridges incompletely divide the pharynx into a dorsal respiratory or branchial portion and a ventral digestive portion. Ventral digestive portion lined with ciliated epithelium with gland cell & helps in food concentration.

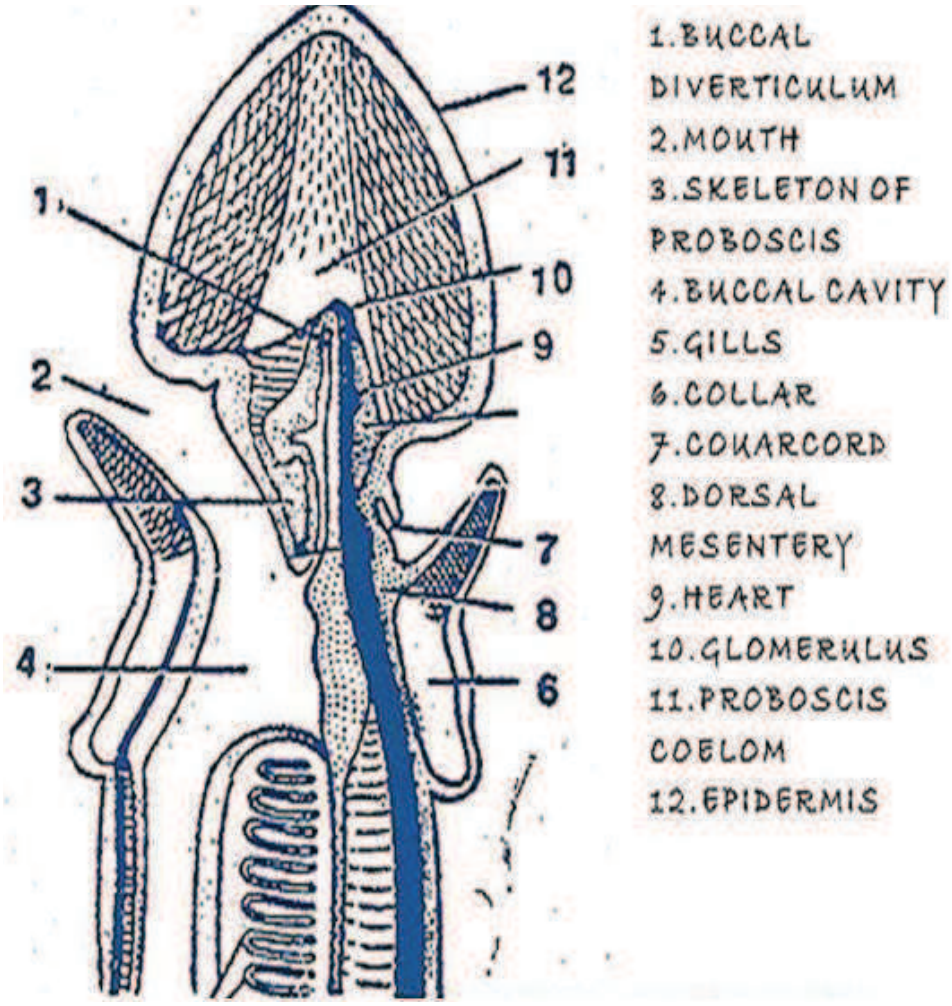


Fig.2.13 Digestive system of Balanoglossus

(iv) Oesophagus:

Behind the last pair of gill slits the pharynx continues into the short oesophagus. The dorsal part of the oesophagus is called post branchial canal which possesses thick folded and glandular epithelium. Posterior part of oesophagus reduces in diameter and has deeply furrowed epithelium.

(v) Intestine:

It occupies hepatic and post hepatic region of trunk. Intestine also extends intestinal caecum corresponding to the hepatic caeca of this region. Post hepatic region of intestine is connected with the ventral body wall by the pygochord.

(vi) Anus:

Intestine opens to the exterior by a terminal circular aperature, the anus at the tip of the trunk. It is often surrounded by a sphincter muscle.

(l) Food, feeding and digestion:

Balanoglossus is a cilliary feeder. Its food comprises of microscopic organisms and organic particles present in water and the bottom sand in which it makes its burrows.

A respiratory cum food water current is set up by the lateral cilia of gill slits. It enters the mouth, passes through the buccal cavity, pharynx, gill slits and branchial sacs

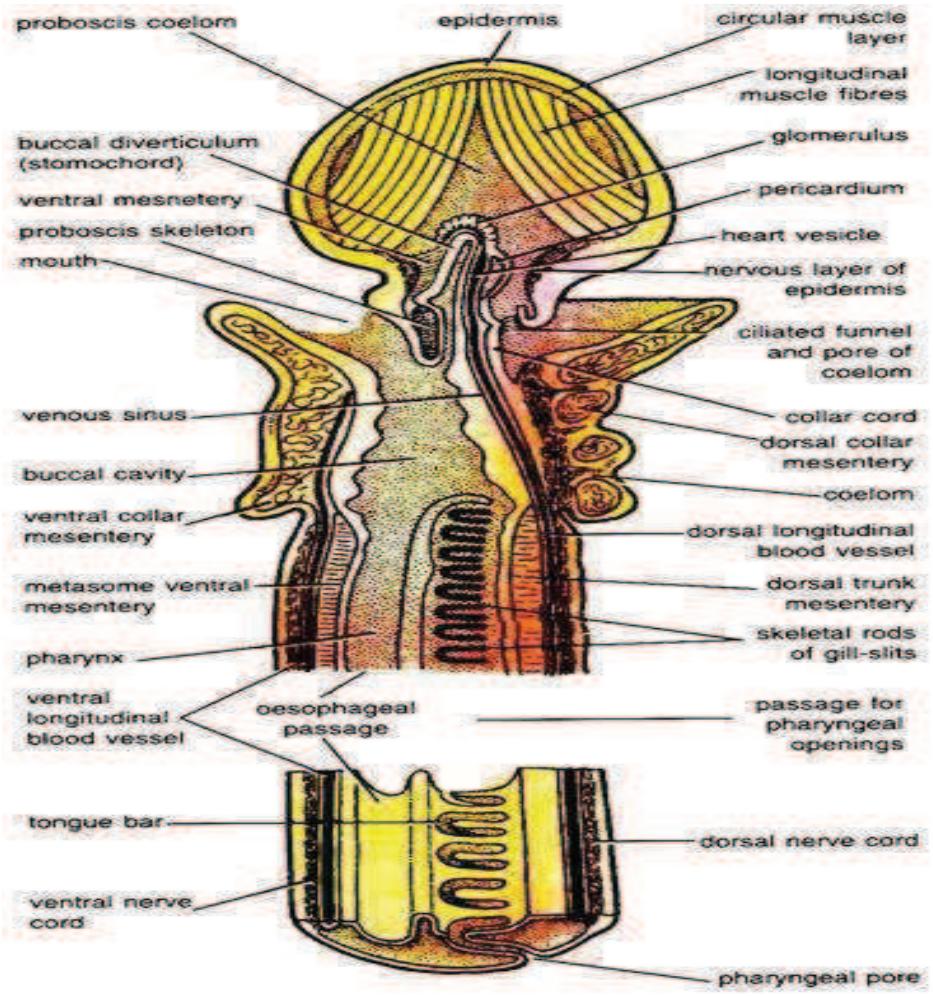


Fig 2.14.Food, feeding & digestion in Balanoglossus

and leaves through the gill pores. The food, present in the water current is collected by the mucus, secreted by the proboscis gland cells in the form of mucus string. This mucus string is directed towards the pre-oral ciliary organ at the base of the proboscis by the cilia covering the proboscis.Then it goes back to the mouth. U-shaped pre oral ciliary organ tests the quality of food and water entering the mouth.Backward movement of food through the alimentary canal is maintained by the ciliated lining of its walls.Digestion takes place by enzymes secreted by gland cells of the pharynx, oesophagus and hepatic region of the intestine.Exact process of digestion in Balanoglossus is not known. Undigested substances, along with sand and silt pass out through the anus as "castings".

(m) Respiratory system.

The respiratory apparatus of Balanoglossus comprises: The branchial sacs that open out through gill-pores and the branchial portion of pharynx bearing gill-slits.

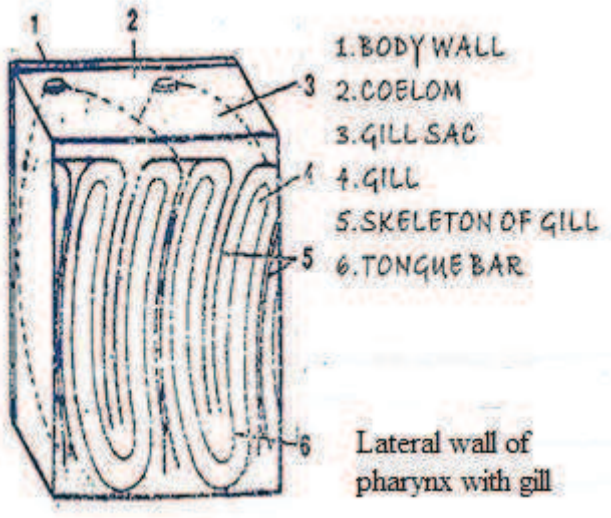


Fig.2.15Respiratory system of Balanoglossus

(n)Branchial pharynx:

Two lateral longitudinal parabranchial ridges divide the pharyngeal cavity into a ventral digestive portion and a dorsal respiratory or branchial portion.Dorso-laterally,on each side,the branchial portion is perforated by a longitudinal series of numerous U-shaped opening, the gill-slits.Their number varies and increases as the animal growa older.at the start of development, a gill-slit is a broad oval slit. Later, a hollow projection of dorsal pharyngeal wall, called tongue bar, grows into the making it U-shaped.A tongue bar is connected with adjacent gill septa by short transverse or horizontal connections, the synapticula. The development and arragement of gill-slits is identical with that found in Branchiostoma.The gill-slits are richly lined by cilia, called lateral cilia.

(o)Mechanism of respiration:

The lateral cilia lining the gill-slits set up a food-cum-respiratory current of water. It enters the pharynx through mouth, then passes through gill-slits into the branchial sacs and finally leaves through the gill pores. The tongue bars are richly vascular and participate in gaseous exchange. The blood of their capillary networks takes up the oxygen dissolved in water and returns carbon dioxide to it.

(p)Nervous system:

The nervous system is of primitive type resembling that of coelenterates and echinoderms.Nervous layer is thickened along definite strands to form two

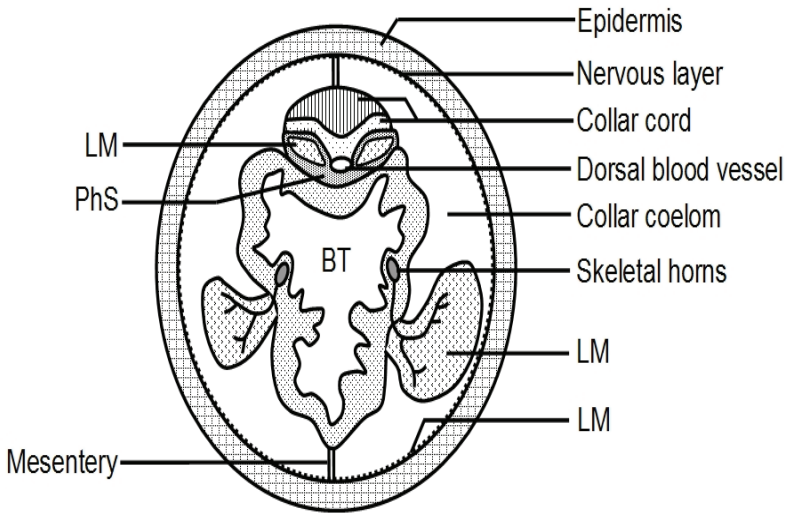


Fig.2.16 Nervous system

Main nerve cords, one mid-dorsal and other mid-ventral, which runs along the entire length of the trunk. Ventral cord extends upto collar-trunk septum where it connects with the dorsal cord by circular strands, called circumenteric nerve ring. Dorsal cord extends anteriorly upto the base of proboscis where it is connects with other circular strands called anterior nerve ring. Dorsal cord leaves the epidermis and traverses the collar coelom as collar cord. The collar cord contains a cavity called neurucoel.

(q) Reproductive System:

Balanoglossus performs asexual and sexual reproduction.Gilchrist described asexual reproduction in Balanoglossus capsensis. In the summer season its posterior end will divide into a number of bits. Each bit will develop into a new individual.Sexes are separate, sexual dimorphism is absent. The gonads are

simple. They are present in one or many rows in branchio genital region, fertilized zygote undergo holoblastic clevage. In Balanoglossus kowaiowsley the development is direct. No larval form is seen in its life history. In other species of Balanoglossus a larval form called 'Tonaria" is seen in the development. It will undergo metamorphosis and becomes adult.

(r) Development:

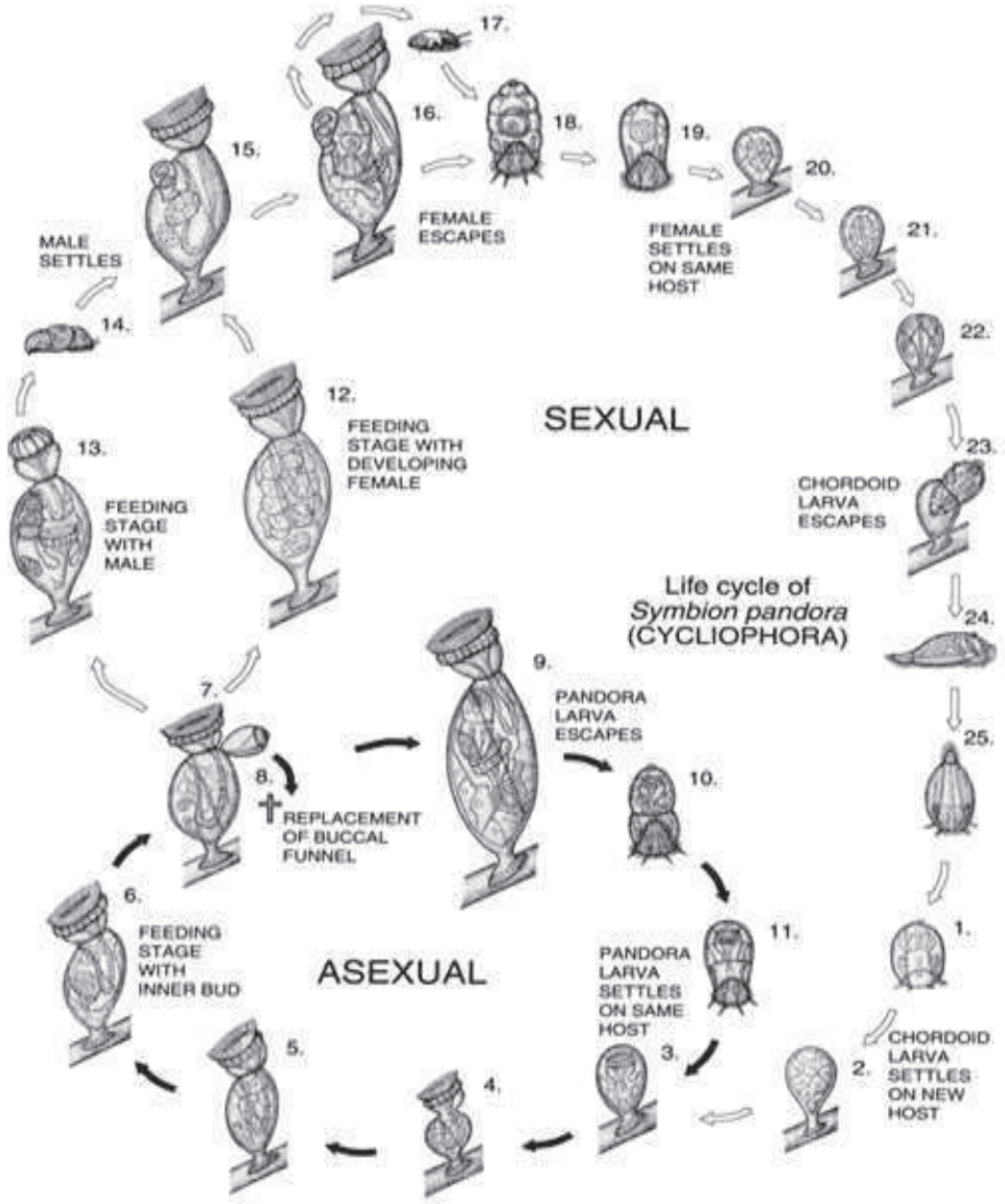


Fig.No.2.17 Life cycle of Balanoglossus

The fertilized egg contains some amount of yolk. It is mesoelecithal egg.It undergoes holoblastic clevage.Because of clevage it gives Morula, blastula stagesIn Blastula stage a cavity is present called Blasto coel.The blastula is round in the beginning then it becomes flatIt undergoes invagination and gives two layered gastrula..This stage will show blastopore, which will slowly closer. This stage will develop cilia. It will also develop apical tuft. It shows ectoderm and endoderm. It will develop enterocociic coelom. At this stage the ciliated embryo will be liberated into water. It elongatesand transforms into tornaria" larva.

2.4.2 AFFINITIES OF BALANOGLOSSUS

Affinities of Balanoglossus with Annelida & Echinodermata:-

Spengel (1893) suggested **affinities of Hemichordata (Balanoglossus) with Annelida** as follows:-

1. Bodies of both are vermiform and coelomate.
2. Both have Burrowing habits and tubicolous life. Both ingesting mud which is passed out as castings through anus.
3. Collar of *Balanoglossus* is similar to clitellum of earthworm.
4. Proboscis & prostomium is similar & preoral.
5. The arrangement of blood vessel is similar.
6. Position of heart in both is dorsal.
7. Tornaria larva of *Balanoglossus* shows several structural resemblances with the Trochophore larva of Annelida in being pelagic, ciliated, with apical plate, eye spots, and sensory cilia & well developed alimentary canal with similar parts.

Affinities of *Balanoglossus* with Echinodermata:-

Adult resemblances:-

Adult *Balanoglossus* and echinoderms are structurally quite different. So it is difficult to draw their phylogenetic relationship between themselves. However some resemblances are:-

1. Enterocoelic origin of coelom.

2. Heart vesicles and glomerulus of *Balanoglossus* are considered homologous to the dorsal sac and axial gland of echinoderm.
3. Nervous system poorly developed and forms epidermal nerve plexus.
4. Proteins & phosphagens present in *Balanoglossus* closely resemble those of echinoderms.
5. Both have common habits, and remarkable power of regeneration.

B. Larval resemblances:-

Tornaria larva of *Balanoglossus* has striking, structural similarities with Bipinnaria larva of echinoderms as follows:-

i. Both are small, pelagic, transparent and oval.
ii. Identical ciliated bands taking up a similar twisted course.
iii. Enterocoelic origin & similar development of coelom.
iv. Proboscis coelom of Tornaria is comparable to hydrocoel of echinoderm Dipleurula.
v. Deuterostome & digestive tract and complete are in both.

Chordates affinities of Balanoglossus**:-**

Inclusion of *Balanoglossus* under phylum chordata is not universally accepted.Among 3 fundamental chordate character the nature of notochord is really questionable. Recent workers do not accept the notochordal nature of buccal diverticulum.Beside this The nervous system, in general, is typically non chordate type excepting the presence of lumen in collar nerve cord.The only important chordate feature is the presence of gill slits.

Affinities with Urochordata:-

Similarity is present in the pharynx and branchial apparatus of both.Development of the Central part of the nervous system is quite similar in both

Affinities with Cephalochordata:-

Similarity is found in the structure and function of branchial apparatus in both.Arrangement

of coelomic sacs is also similar in both.

2.5 SUMMARY

The hemichordates are bottom-burrowing animals, solitary, particularly marine and cosmopolitan that inhabit soft sediments (Mandal, 2012). They are deposit feeders with a great importance in the food chains and also to recycle nutrients, break algae mats and mix marine sediments (EcoMarines 2013).They have bilateral symmetry, worm-like body divided into three regions,(Mandal, 2012).Mainly due to the presence of stomochord and character of the larvae, They are believed to be an connecting linkedbetween a chordates and non-chordata (Mandal,2012).Although they are important for the whole marine environment balanceand maintenance, there are only a few studies about it.

2.6 GLOSSARY

Collar A distinct body region between the proboscis and the trunk that is attached to the proboscis on a medio-dorsal stalk. The ventral mouth opens anterior to the collar.

Deuterostomes. A bilaterian lineage of animals classically defined by the formation of mouth and anus: the blastoporal opening (site of gastrulation) becomes the anus and the mouth forms secondarily, later in development.

Direct development. Development to an adult body plan without an intervening larval stage with a distinct body plan.

Echinoderm. Member of a phylum of marine invertebrates comprising echinoids (sea urchins), asteroids (sea stars), crinoids (sea lillies), holothuroids (sea cucumbers) and ophiuroids (brittle stars).

Enterocoely. An embryonic phenomenon, during which mesodermal coeloms form out-pocketing of a part of the embryonic gut.

Gonochoric. Having only one, male or female, set of reproductive organs.

Holoblastic cleavage. The cleavage furrow extends through the entire egg or blastomere, resulting in a complete cleavage.

Indirect development. Development to an adult via a distinct larval form followed by metamorphosis.

Lecithotrophic. Having a swimming, non-feeding larva that derives its nutrition from maternally provisioned yolk.

Notochord. An embryonic rod-like structure that is located on the dorsal part of the developing animal and is essential for initiating the differentiation of the adult nervous system.

Proboscis. The highly contractile and expandable anteriormost part of a hemichordate that is used for burrowing and locomotion.

Radial cleavage. After cleavage, the daughter blastomeres are either perpendicular or parallel to each other. This type of cleavage is characteristic of deuterostomes.

Zooid. A single animal that is part of a colonial structure.

2.7 SELF ASSESSMENT QUESTION

Multiple Choise Question

1. Balanoglossus belongs to the group:

(a) Platyhelminthes
(b) Annelida
(c) Cephalochordata
(d) Hemichordata

2. Balanoglossus is commonly known as:

(a) Snake worm
(b) Acorn worm
(c) Corn worm
(d) Earth worm

3. Larval form of Hemichordata:

(a)Tornaria

(b) Crinoidia

(c) Nauplius

(d) Caterpillar

4. Advanced chordates originated from:

(a) Amphioxus
(b) Tachoglossus
(c) Balanoglossus
(d) Starfish

5. Musculature in Balanoglossus is:

(a) Smooth
(b) Cardiac
(c) Striated
(d) Transverse

6. Coelom in Balanoglossus is:

(a) Scizocoel
(b) Entercoel
(c) Holocentric
(d) Metacentric

7. Balanoglossus is:

(a) Surface feeder
(b) Bottom feeder
(c) Column feeder
(d) Ciliary feeder

8. Which of the following is true for blood vascular system of Balanoglossus?

(a) Closed
(b) Absence of central sinus
(c) Blood is colourless
(d) Arteries and veins are absent

9. Body in hemichordate is:

(a) Segmented
(b) Radially symmetrical
(c) Diploblastic
(d) Triploblastic

10. Fertilization in Hemichordata is:

(a) Internal
(b) External in freshwater
(c) External in sea water
(d) External in air

Answers

1(d) 2 (b) 3 (a) 4(c) 5 (a) 6(b) 7 (d) 8 (c) 9(d) 10 (c)

2.8 SUGGESTED READING

3. Nigam, H.C.1983.Zoology of chordates, Vishal publication, Jalandhar.
4. Kotpal, R.L 2012.Vertebrata, Rastogi publication Merruth.

2.9 TERMINAL QUESTIONS

Q1. Give the general characters of Hemichordata?

Q2. Give the classification of Hemichordata?

Q3. Describe the habit, habitat and external morphology of Balanoglossus?

Q4 Why is the Balanoglossus is considerd as connecting link between Chordatata and

Nonchordata?

Q5 Describe the respiration in Balanogloussus?

Q6 Describe the food and feeding habit of Balanogloussus?

Q.7 Discuss the affinities of Balanoglossus

Q8. Describe the characteristics of hamichordata?

Q9. Why Balanoglossus is classified under Hamichordate?

Q10. Give general charaters of balanoglousses?

2.10 REFERENCES

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2. Kotpal, R.L 2012.Vertebrata, Rastogi publication Merruth.
3. Nigam,H.C.1983.Zoology of chordates,Vishal publication,Jalandhar
4. Some figure and tax material are adopted from Wikipedia.
5. Some figure and tax material are adopted from Biozoomer.

UNIT 3: UROCHORDATA

CONTENTS

3.1 OBJECTIVE

- To understand the systematics and functional morphology of Urochordates.
- To study their affinities and adaptations to different modes of lives.
- To describe and explain the basic biology, evolution and development of Urochordata.
- To impart knowledge in comparative anatomy and development of urochordata

3.2 INTRODUCTION

The urochordates, sometimes known as the tunicates, are commonly known as "sea squirts. The body of an adult tunicate is quite simple, being essentially a sack with two siphons through which water enters and exits.Water is filtered inside the sack-shaped body.Urochordates are small marine animals with larvae that swim freely and adults that attach themselves to the ocean floor. The 1,300 species of urochordates, like all members of the phylum Chordata, possess four characteristic anatomical structures as embryos: a flexible body-length rod **notochord** that provides resistance against muscular contractions and allows for more efficient movement; a **dorsal**, hollow, **nerve cord** that forms the central nervous system; slits in the beginning of the digestive tract (the pharynx) that allow filter feeding and gas exchange; and a **postanal tail**.

3.3 *GENERAL CHARACTERISTICS AND CLASSIFICATION*

3.3.1 GENERAL CHARACTERISTICS

These animals are known as ‘sea squirt’. The tunicates were first regarded as sponges. Lamark in 1816 placed Tunicata in between the Radiata and Vermes in his system of classification. Later, they were included in Mollusca. In 1866 Kowalevsky kept them in chordates. Their chordate features are clearly seen in the larval stages. All Urochordates are marine and occur in all the seas. Majority of them are sedentary and some are pelagic. The life-history of urochordates passes through a dramatic change. Their chordate characters are more pronounced during larval period. While in adults they are more like invertebrates than chordates. Therefore, the characters are described in two heads — larval characters and adult characters.

1. Body shows variation in size and form.
2. The body is unsegmented and has no tail
3. The body is covered by a test. It is formed by tunicine which is rallied to cellulose. Hence the name Tunicata
4. Body wall shows one-layered epidermis, dermis is made by connective tissue and muscles, and atrial epithehum.
5. Celome is absent.
6. Atrial cavity surrounds the pharynx, into this cavity the gill slits, anus and genital ducts will Open. It opens through atrial aperture.
7. Larva has notochord in the tail. It disappears during metamorphosis.
8. Respiratory system contains gills in the pharyngeal wall.
9. Ciliary mode of feeding is common.
10. Open type of Circulatory system is seen.
11. The heart is ventral and it periodically reverses its function.
12. Nervous system is represented by a single dorsal ganglion in the adult.
13. Excretion is carried on by nephrocytes.
14. Asexual reproduction is by budding.
15. Bisexual animal and cross fertilisation is favored.
16. Fertilization is external.

3.3.2 CLASSICFICATION UP TO ORDER LEVEL

Subphylum Urochordata is divided into three classes.

CLASS 1. ASCIDIACEA

CLASS 2. THALIACEA

CLASS 3. LARVACEA (APPENDICULARIA)

CLASS 1. ASCIDIACEA:

i. These are sedentary tunicates.
ii. The body is covered by a test.
iii. Pharynx is large and contains gill-slits.
iv. Notochord, nerve-cord and tail are absent in adults.
v. These are bisexual animals.
vi. Life-history includes a typical tadpole larva.

The class is divided into two orders.

Order 1. Enterogona

These ascidians bear one gonad in the intestinal loop. Neural gland is ventral to the ganglion. Tadpole larva is seen.

Ex: Ascidia and Ciona.

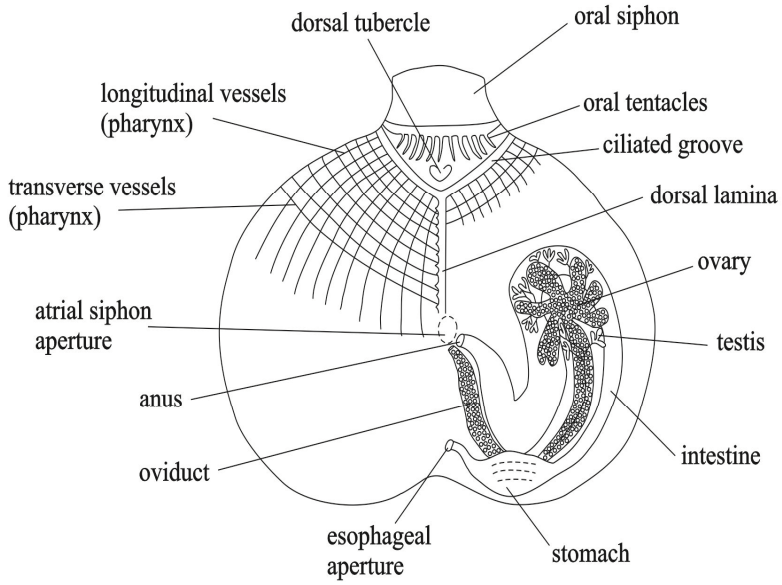


Fig. 3.1: Internal Structure of Ascidia

Order: 2. Pleurogona.

In these ascidians, gonads are paired and are present in the atrial wall. Neural gland is dorsal to the ganglion:

Ex: Herdmania, Botryllus.

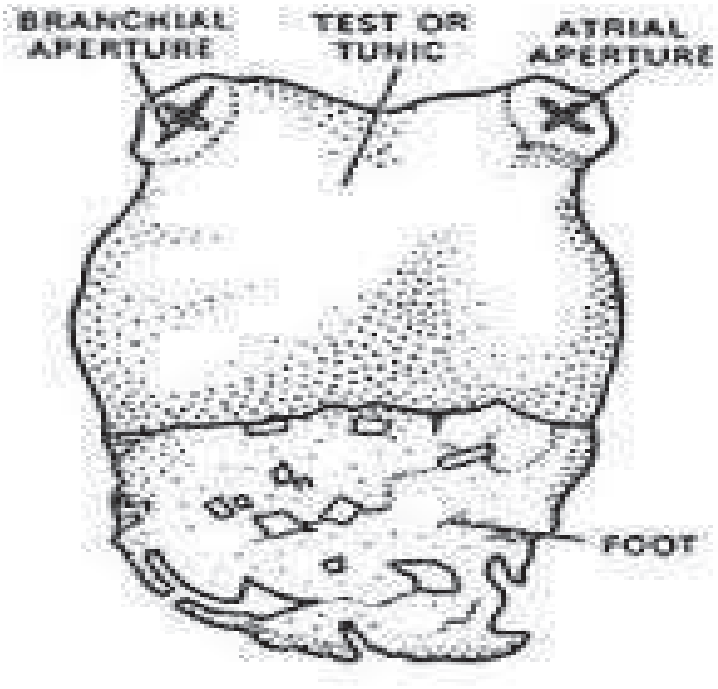


Fig 3.2 Test of Herdmania

CLASS 2.THALIACEA:-

i. These urochordates are free-swimming and pelagic forms.
ii. They are covered by transparent test.
iii. The brachial and atrial apertures are placed at anterior and posterior ends.
iv. Pharynx is small.
v. Notochord, nerve-cord and tail are absent in the adult.
vi. Asexual reproduction is by budding.
vii. These are bisexual animals.
viii. Tailed larva may be present or absent.
ix. Alternation of generations can be seen in the life history.

The class Thaliacea is divided into three orders.

Order1. Doliolida (Cyclomyarla)

i. Barrel shaped body is completely covered by muscle bands,
ii. Pharynx is small.
iii. Number of gill slits is less.
iv. Tailed larva is seen.

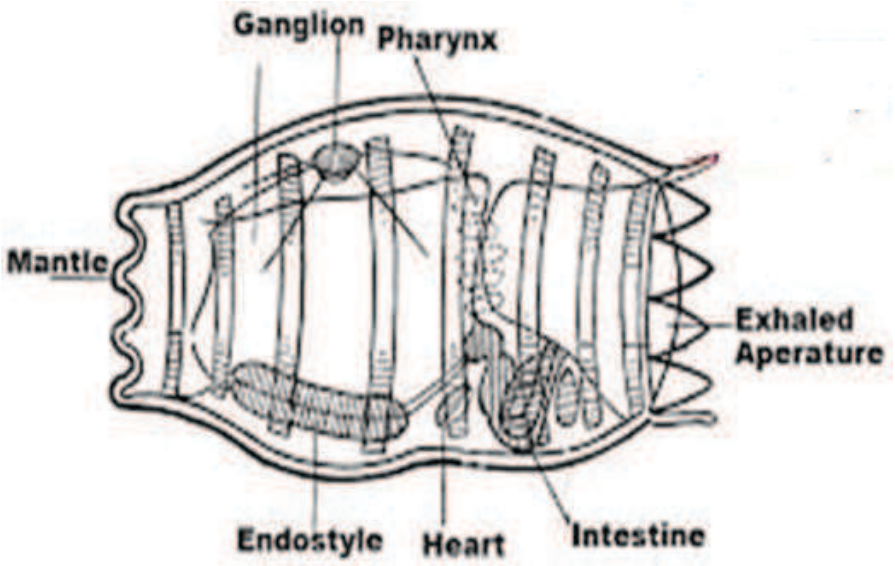


Fig 3.3: Doliolum

v. Sexual Blasto-zooid and asexual oozooid stages will alternate in the life cycle. Ex: Doliolum.

Order2. Pyrosomlda:

i. This order includes colonial forms.
ii. Muscle bands are small and present at the ends.
iii. Gill-slits are many.
iv. Tailed larval stage is absent.
Ex: Luminescent colonial form.

Order 3. Salpida (Hemimyaria):-

i. Muscle bands are complete dorsally and incomplete ventrally.
ii. This order includes organisms whose body prism is like.
iii. Only one pair of lateral gill slits are present.
iv. Tailed larval stage is absent.

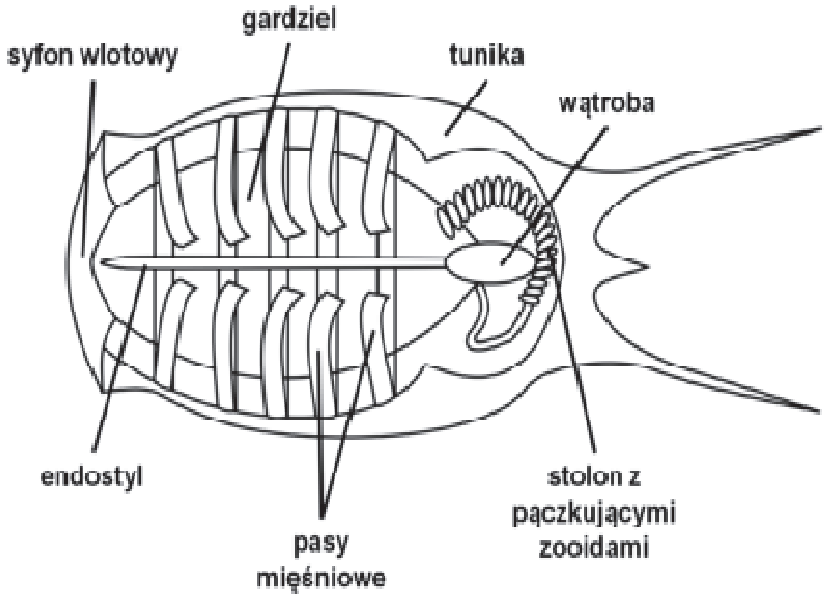


Fig: 3.4 Salpa

v. Life history includes alternation of generations.
Ex: Salpa.

CLASS: 3. LARVACEA (APPENDICULARIA)

- These are free – swimming pelagic tunicates.
- True test covering is lacking.
- They show loose gelatinous house.
- This house is useful for filter feeding.
- Two gill slits are present.
- Atrium is absent.

- Notochord and nerve cord are persistent
- They show tail throughout their life.
- Neotenic forms are included.

  Ex: Oikopleura. ‘

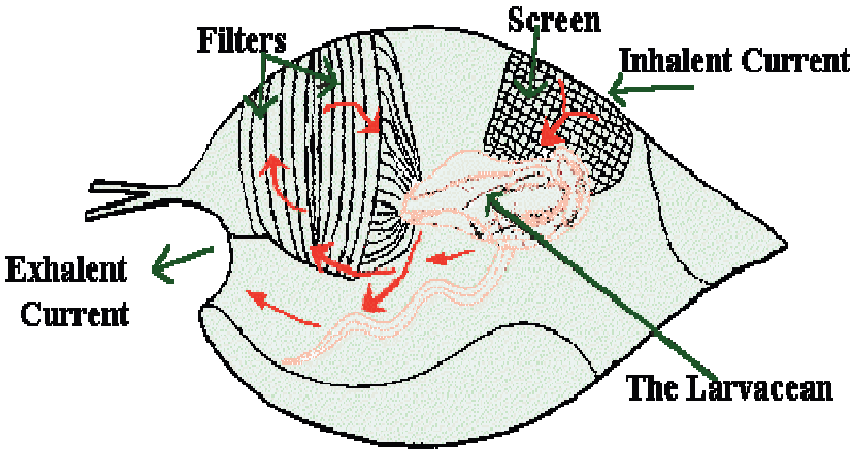


Fig 3.5 A Larvacean in it’s house

3.4 TYPE STUDY OF HERDMANIA

3.4.1 GENERAL STUDY

Systematic position:

Phylum – Chordata

Class – Acidiacea

Order – Pleurogona

Suborder – Stolidobranchia

Genus- Herdmania

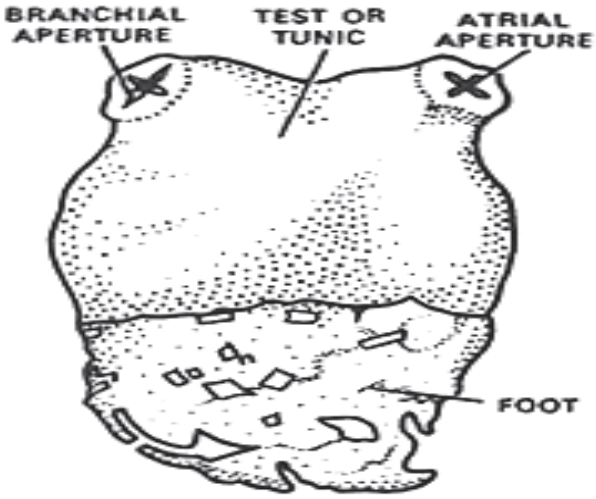


Fig: 3.6 Hardmania in test

HABIT AND HABITATE

Herdmania Momus is one of the most commonly encountered species of ascidians.

This solitary ascidian is sometimes referred to as the *red-throated ascidian*, as its two siphons are vivid red in colour. Most solitary ascidians that are encountered are so covered in algae that the coloration is often not visible. When found at depth, the red colourations may not be visible, as lower frequencies of light are absorbed by the layers of water above.

MORPHOLOGY OF HERDMANIA

Body wall

The body-wall of Herdmania is called mantle. It is thick and muscular in the antero-dorsal region of the body. It is thin, non-muscular and transparent in the postero ventral region. It shows epidermis, mesenchyme and inner epidermis.

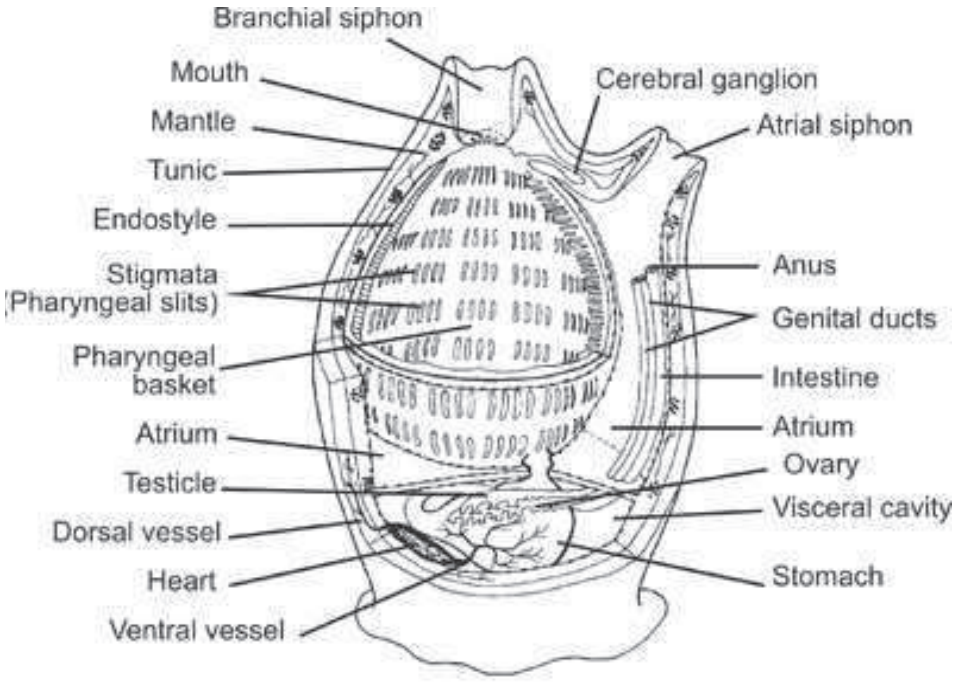


Fig 3.7 Internal organs of Hermania

i. **Epidermis**: is single layer of cells. It covers the branchial and atrial apertures and siphons. The epidermis is interrupted at places where spicules and blood-vessels pass from the mantle into the test.

ii. **Mesènchyme**: develops from the mesoderm. It has connective tissue containing blood-sinuses, muscle-fibers, nerve fibers and cells. The muscle fibers are long and flat. They contain large nuclei.

iii. **Inner epidermis:** is single layer of flat cells. It forms the lining of the atrial cavity.

- The body-wall, protects visceral organs, the outer epidermis secretes the test, while the musculature brings contraction of the body and the siphons

DIGESTIVE SYSTEM

Down from the pharynx is *Herdmania*'s D-shaped gut loop composed of the oesophagus (the decending arm), the stomach (an enlargmenet at the base of the U) and the ascending arm (the intestine) and then the terminal end (the rectum and anus). The oesophagus connects to the branchial sac below the dorsal lamina so that food caught by the branchial sac may be channeled to the stomach (Degnan 1991). The stomach, much like our own, is lined with cells that secrete digestive enzymes and the intestine is likely the site of absorption. A network of tubules called the pyloric gland covers the outer wall of the anterior intestine and opens into the base of the stomach, secreting digestive enzymes, removing blood borne toxins and storing glycogen. Cauliflower shaped liver lobules protrude from the pyloric portion of the gut and the gut loop is loosely associated with the body wall. Excretory organs are lacking and thus Herdmania must rely on diffusion of ammonia across the pharynx. Other metabolic by-products are stored in nephrocytes which accumulate in tissue and are only released at death. This is known as storage excretion.

In Herdmania the digestive system is coiled and complete and contains the following parts**. (fig 3.8)**

Mouth:

It forms the opening of branchial siphon marking the anterior end of the body. It is guarded by four lobes derived from the test.

Buccal Cavity:

Mouth leads into a laterally compressed cavity of branchial siphon, called buccal cavity or stomodaeum. A strong branchial sphincter, present at the base of siphon, regulates the opening of mouth. A circlet of highly branched delicate branchial tentacles, richly supplied by nerves, is also found at the base of siphon. These are 64 in number and are of four different sizes: 8 large (5 mm), 8 medium (2.5 mm), 16 small (1.5 mm) and 32 very small (0.5 mm). The free ends of tentacles meet at the centre forming a sort of strainer which prevents entry of larger food particles into pharynx.

Pharynx:

Buccal cavity leads into the pharynx which occupies the major part of the body or atrial cavity. It is differentiated into a prebranchial zone and a branchial sac.

(a) Prebranchial zone:

This is smaller anterior region having smooth walls without folds, cilia and stigmata or gill slits. It is separated from the branchial sac by two circular thin parallel ciliated ridges called anterior and posterior peripharyngeal bands, enclosing a narrow ciliated peripharyngeal groove.

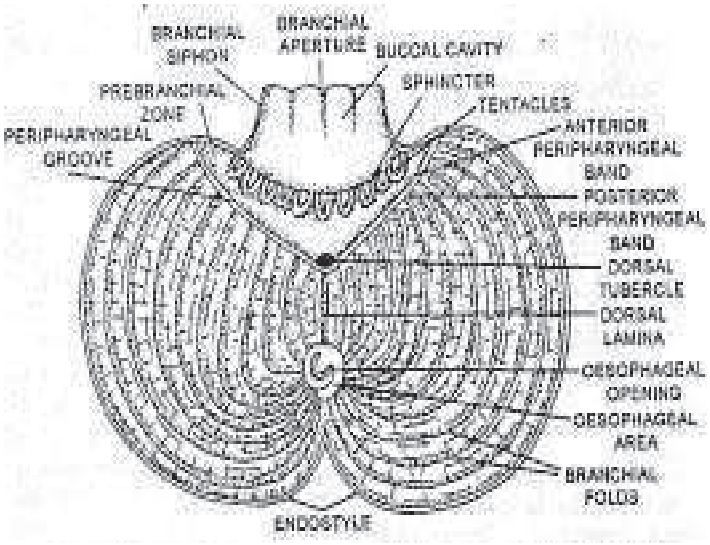


Fig.3.8Herdmania pharynx cut along mid-ventral line.

The anterior peripharyngeal band is a complete ring and mid dorsally in front of it lies a smaller dorsal tubercle made of two spiral coils. The posterior peripharyngeal band is interrupted mid-dorsally by the dorsal lamina and mid-ventrally by the endostyle.

(b) Branchial sac:

This is tlarger posterior region of pharynx and is also known as branchial basket. Because its wall is perforated by numerous gill slits or stigmata, each side of branchial sac bears about 200,000 stigmata arranged in several transverse rows.The epithelial lining of the stigmata bears long cilia called lateral cilia. Pharyngeal wall is divided into stigmatic rectangular areas by longitudinal and transverse bars, each area having 5 or 6 stigmata. All the bars of the wall are highly vascular and contain their corresponding blood vessels. Some other structures also are associated to branchial sac which has their role in digestion.

(i) Trabeculae:

Trabeculae are hollow strands, containing a blood vessel, connecting outer wall of branchial sac to the mantle. The inner wall of branchial sac bears 9 to 10 longitudinal branchial folds to increase its surface area.

(ii) Dorsal lamina:

It is a thin flap or fold extended mid-dorsally from the posterior pharyngeal band. It is 1 to 1.5 cm long, bears 20 to 30 conical tapering tongue like processes called languets. These languets hang down from dorsal lamina into the cavity of the branchial sac. The languets are covered by ciliated epithelium. They form a sort of groove for conducting food.

(iii) Endostyle:

This is a shallow mid-ventral groove lying on the floor of the banchial sac. Anteriorly it joins to the peripharyngeal groove. The marginal folds of endostyle merge with the posterior peripharyngeal band.

These folds reach up to oesophageal opening as thin retropharyngeal folds. Structurally, endostyle consists of five longitudinal ciliary tracts (1 median, 2 lateral pairs) alternating with

four longitudinal tracts of mucus secreting glandular cells. Endostyle is homologous to the hypopharyngeal groove of cephalochordates and thyroid glands of vertebrates.

(iv) Oesophageal area:

The posterior most region of branchial sac has a small circular oesophageal area. Its opening is guarded by two semi-circular lips. This area is devoid of blood vessels, folds and stigmata.

(v) Oesophagus:

It is very short, curved and thick walled tube. It contains four longitudinal ciliated grooves, connects branchial sac with the stomach.

(vi)Stomach:

It is wider than the oesophagus, thin walled, sphinctered at both ends and has a smooth inner lining.

(vii)Intestine:

It is a thin walled, U-shaped tube formed by a proximal, ventral or descending limb and a distal dorsal or ascending limb, both united anteriorly. The intestinal loop thus formed encloses the left gonad.

(viii)Rectum:

Intestine leads into the rectum, internally lined by cilia. It curves dorsally to open into the atrium or cloaca through the anus. Anus is guarded by four lips.

(ix)Cloaca:

The atrium or cloaca leads into the atrial siphon and opens outside through the atrial aperture.

NERVOUS SYSTEM

The dorsal hollow nerve cord of all ascidians is lost during larval metamorphosis leaving the adult body plan secondarily simplified and divergent from other chordates. Remnants of the neural tube form the brain and the neural gland. The brain, termed the cerebral ganglion, is located in the connective tissue between the two siphons. The nerves here control body, pharynx and siphon contraction. The neural gland lies

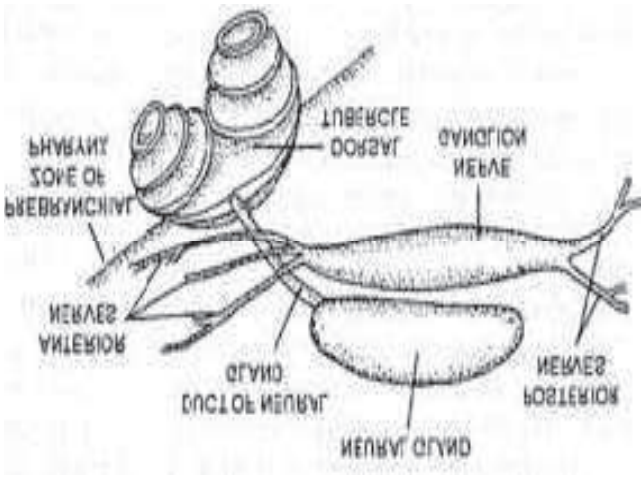


Fig 3.9 Neural Gland and nerve ganglion Herdmania

beneath the brain but actually has no nerves. Sensory organs are alsolost during the transition from larvae to adult but sensory cells remain on the surface of the siphons, Buccal tentacles on the atrium are used to control the water flow through the pharynx.

CIRCULATORY SYSTEM

The circulatory system is well developed and closed type. It includes (i) heart and pericardium (ii) blood vessels and (iii) Blood.

(i) Heart and Pericardium: is a non contractile, elongated and transparent tube about 7.0 cm long and 3.0 mm wide running obliquely below the right gonad.

It is closed at both the ends and is filled with a colourless pericardial fluid with corpuscles similar to those of blood. Its wall is thick, made of connective tissue and contains blood sinuses and is internally lined by squamous epithelium.The heart is enclosed within the pericardium and is attached to its wall along its entire length by a thin mesentery like connective tissue flap.It is formed by an infolding of the pericardium but it is highly contractile, thin walled and contains striated muscles.Both ends of the heart are open. There are no valves but a pear shaped body present midway in the pericardial body which probably regulates the flow of blood in the heart

(ii) Blood Vessels:

The major blood vessels have definite walls, but the smaller ones lack them.

(a) Ventral aorta:

The ventral or subendostylar vessel is the largest vessel of the body arising from the ventral end of the heart. At its point of origin it first gives out a stout ventral test vessel supplying blood to the ventral side of the test.It then bifurcates into an anterior and a posterior hypobranchial branch running below the entire length of endostyle. Both the branches give off 40-56 pairs of transverse vessels to wall of branchial sac and several fine vessels to the endostyle and mantle. The anterior branch joins two circular vessels at the base of branchial siphon- peripharyngeal vessel and sub-tentacular vessel.

Lateral branch sends tentacular branches into each tentacle and 6-8 siphonal vessels into the branchial siphon. The posterior branch supplies a minor branch to oesophagus area.

(b) Dorsal aorta:

It is a stout vessel lying mid-dorsally on the dorsal wall of branchial sac. It is not connected to the heart, but communicates ventral aorta through 5-7 pairs of transverse vessels of the branchial sac and the circular peripharyngeal and subtentacular vessels. Dorsal aorta supplies branches to neural complex dorsal tubercle and 6-8 siphonal vessels into the mantle of branchial siphon.

(c) Branchio-visceral vessel:

It arises from posterior part of the dorsal aorta and immediately divides into two branches. First branch, right oesophageal vessel is short and supplies the right liver lobe and right side of oesophgus. Second branch, the ventro-intestinal vessel is stout and long and supplies blood to left side of oesophgus, stomach, intestine rectum, left gonad and left liver lobe.

(d) Cardio-visceral vessel:

It arises from the dorsal end of the heart and supplies blood to several organs. Immediately near origin it sends a right hepatic vessel to right liver lobe and an oesophageo-test vessel to oesophagus and test.A main dorsal branch sends a test vessel, a left oesophageal and a right gonadial vessels to supply blood to respective organs. It also gives off 6-8 siphonal vessels into the wall of atrial siphon. A middle branch or left gonadial vessel passes obliquely into the left gonad. The main ventral branch soon divides into a dorso- intestinal vessel to left liver lobe, stomach and intestine, a gastric vessel to stomach and a dorsal test vessel to test.

(iii) Blood:

Blood is slightly reddish, transparent and hypertonic to sea water. It contains a few colourless, amoeboid leucocytes, 6 to 7 types of coloured corpuscles with or without nucleus and the nephrocytes having vacuoles and colloidal cytoplasm. Pigment found in corpuscles may be orange, yellowish-brown or yellowish-green but never red and doesn't take part in respiration.

Course of circulation:

In Herdmania, there is no valve in the heart and the flow of blood is maintained by peristaltic waves. The heart of ascidians is unique in the animal kingdom for changing the direction of flow of blood through it by reverse peristalsis at regular intervals. The arteries and veins change their roles when reversal of flow of blood occurs periodically. When the heart-beats ventro-dorsally it pumps oxygenated blood into the cardio visceral vessel which is distributed to the various parts of the body.The de-oxygenated blood from viscera is collected by the branchio-visceral vessel and passes through dorsal aorta to finally reach into the transverse branchial vessels for oxygenation. During reversal phase, the de-oxygenated blood collected through cardio-visceral vessel from viscera is pumped into ventral aorta and is distributed into transverse branchial peripharyngeal, subtantacular and test vessels. The blood now gets oxygenated and is collected by dorsal aorta and

distributed once again to viscera through branchio-visceral vessel. Deoxygenated blood from viscera is collected by cardio-visceral vessel and brought back to the heart to restart the cycle.

REPRODUCTIVE SYSTEM

There is a single long gonad. The gut loop encloses the left part of the gonad at the posterior end. It has a long deep orange ovary, overlain by a light orange test . The oviduct and sperm duct are separate, run parallel to the intestine and open into the atrium near the anus. Eggs and sperms travel to the cloaca in small amounts nightly through a process called trickle spawning.

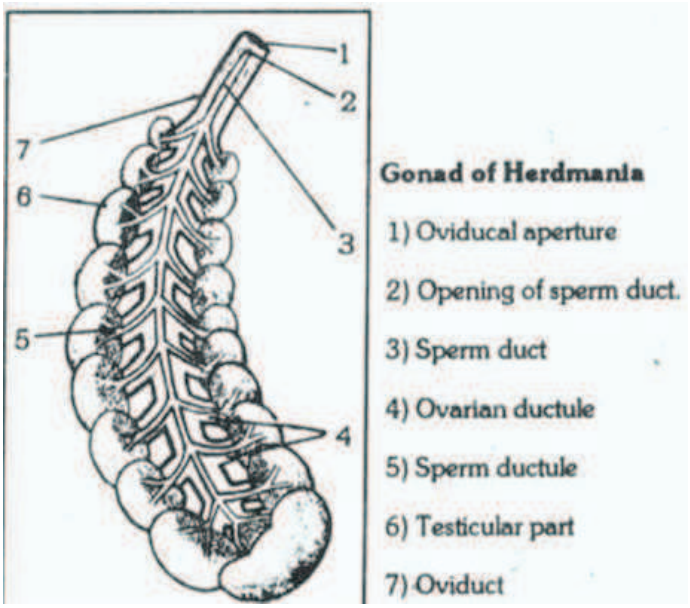


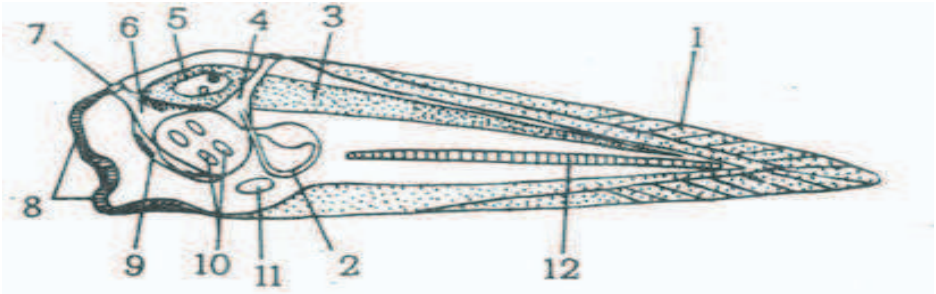
Fig 3.10 Gonad of Hardmania

After fertilization, zygote formation and cleavage of larva known as teadpole larva hatches out of the egg, it becomes an adult after hetrogressive metamophasis.

RETROGRESSIVE METAMORPHOSIS IN HERDMANIA

Metamorphosis is a change from the juvenile to adult stage in which larval stage is quite different from the adult stage. In retrogressive metamorphosis the larva possesses advanced characters which are lost during the development and the adult is either sedentary or degenerated with primitive characters. Urochordate adults, being sedentary show degenerative

characters while the free swimming tadpole larva shows advanced chordate characters which are lost during metamorphosis. Parasitic crustaceans, like *Sacculina* and copepod parasites and stylopids and scale insects (Insecta) also show retrogressive metamorphosis.



Tadpole larva of Herdmania

1) Tail fin	2) Intestine	3) Nerve cord
4) Atrial cavity	5) Sensory vesicle	6) Ciliated diverticulu
7) Oral aperture	8) Adhesive papillae	9) Endostyle
10) Stigmata	11) Heart	12) Notochord

Fig 3.11 Tedpole Larva of Hardmania

TADPOLE LARVA

The tadpole larva of *Herdmania* is only 1-2 mm long when it hatches out of the egg. It does not feed and hence has only 3 hours of survival during which it has to swim about in search of a suitable substratum for attachment. The larva needs advanced features for its free swimming existence, which is so necessary for dispersal of the population to distant places which the sedentary adult has no means to do.

The advanced chordate characters of the larva:

- There is a rod-like notochord in the tail to which are attached muscle bands for swimming.
- There is a dorsal hollow nerve cord which is enlarged to form brain at the anterior end. A photoreceptor ocellus and a balancing organ, the statocyst are attached to the brain.
- There are only two pairs of gill slits in pharynx but the mouth is closed by a membrane and intestine is rudimentary.

- Endostyle on the ventral side of pharynx is very well developed which functions like thyroid gland and helps in metamorphosis.
- Heart is on the ventral side of gut but is non-functional.
- The larva possesses three ectodermal adhesive papillae on the anterior end which help in firm attachment on the substratum.

Changes in larva during metamorphosis:

- Larva attaches to the substratum with the help of chin warts, head downward and tail up.
- Rapid growth takes place between the chin warts (adhesive papillae) and mouth and almost no growth on the opposite side of body.
- Due to rapid growth on one side, body starts rotating in such a way that mouth gradually migrates to the upper side.

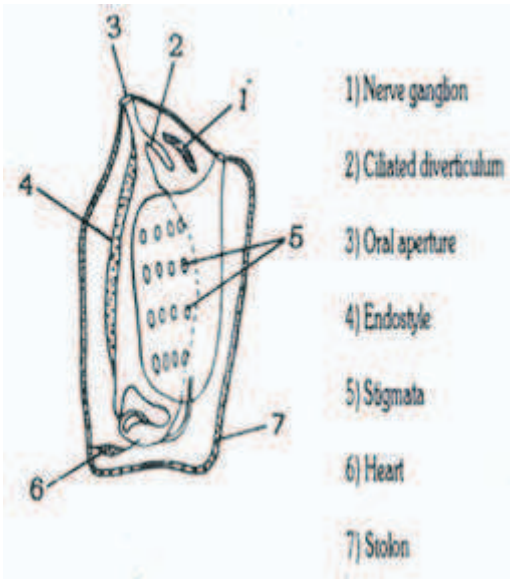


Fig 3.12 Development of young organism

- Meanwhile pharynx enlarges and stigmata increase in number. Intestine becomes functional and atrial opening is formed on the opposite side of oral aperture.
- Both tail and notochord are gradually absorbed in the body during metamorphosis.

- The hollow nerve cord is reduced into a solid nerve ganglion on the dorsal side.
- Sense organs, namely ocellus and statocyst are lost.

When the metamorphosis is over, *Herdmania* is transformed into a bag-like sedentary animal attached to the rock by a foot and having branchial and atrial openings for inlet and outlet of water respectively. Pharynx becomes enormously enlarged with a large number of stigmata for filter feeding and digestive system becomes well developed. However, other advanced chordate characters of the larva are degenerated into simple structures, due to which it is called retrogressive metamorphosis.

3.4.2AFFINITIES

The typical tunicate looks like a non-chordate animal. If the life history of such animal is studied, the larval form reveals the chordate characters of that animal.

Urochordate's-resemblance with Chordate. :-

Urochordates resemble the chorates owing to the following features-

- Presence of dorsal tubular nerve cord.
- Presence of notochord.
- Well developed pharynx with gill-slits.
- Presence of endostyle on the ventral side of the pharynx.
- Presence of atrium around the pharynx.
- Presence of post - anal tail with tail fin.

  Because of these chordate features tunicates are included in chordate's group.

Urochordate's-resemblance with Amphioxus (Cephalochordata):

- Presence of notochord.
- Presence of dorsal tubular nerve cord.
- Presence of large pharynx with gill slits.
- Presence of atrium and atriopore.
- Presence of muscle band.

Thus, the urochordates show close relation with Cephalochordates.

Urochordates differ from other chordates owing to the following characters:

- Presence of retrogressive metamorphosis.
- Absence of segmentation.
- Because of these characters zoologists included these animals in a separate sub-phylum Urochordata.
- During recent years many zoologists regarded the tunicates as primitive and ancestral forms of chordates as a whole.

3.5 SUMMARY

The urochordates are exclucively marine animals living on the substratum. The most familiar member of the group is *Hardmania;* it possesses two siphons for the entry and exit of water. Characteristically they have a larval stage which undergoes retrogressive metamorphosis giving rise to the adult animal.Urochordates show all the basic characters of chordata at one or the other stage of life, they are supposed to be lower than Cephalochordata but higher than hemichorates from evolutionary point of view.

3.6 GLOSSARY

Cephalochordata

Chordate clade whose members possess a notochord, dorsal hollow nerve cord, pharyngeal slits and a post-anal tail in the adult stage.

Chordata

Phylum of animals distinguished by their possession of a notochord, a dorsal hollow nerve cord, pharyngeal slits, and a post-anal tail at some point during their development.

Craniata

Clade composed of chordates that possess a cranium; includes Vertebrata together with hagfishes.

Cranium

Bony, cartilaginous, or fibrous structure surrounding the brain, jaw, and facial bones.

Dorsal hollow nerve cord

Hollow, tubular structure derived from ectoderm and is located dorsal to the notochord in chordates.

Lancelet

Member of Cephalochordata; named for its blade-like shape.

Notochord

Flexible, rod-shaped support structure that is found in the embryonic stage of all chordates and in the adult stage of some chordates.

Pharyngeal slit

Opening in the pharynx.

Post-anal tail

Muscular, posterior elongation of the body extending beyond the anus in chordates.

Tetrapod

Phylogenetic reference to an organism with a four-footed evolutionary history; includes amphibians, reptiles, birds and mammals.

Tunicate

Sessile chordate that is a member of Urochordata.

Urochordata

Clade composed of tunicates.

Vertebral column

Series of separate bones joined together as a backbone.

Vertebrata

Members of the phylum Chordata that possess a Vertebral column.

3.7 SELF ASSESSMENT QUESTIONS

1. Herdmania belongs to group ----------
   a) Hermichordata
   b) Urochordata
   c) Pisces
   d) Gnathostomata
2. In urochorodates the Larva is known as _____
   a) Bipinaria
   b) Tadpole larva
   c) Pluteus
   d) Tornaria
3. Which type of metamorphosis occurs in tadpole larva of Herdmania?
   a) Complete metamorphosis
   b) Partial metamorphosis
   c) Progressive metamorphosis
   d) Retrogressive metamorphosis _____
4. Which of the following terms is not used for Herdmania?
   (a) Undapasi
   (b) Mulaikanna
   (c) Sea squirt
   (d) Sea ski
5. The aperture of siphons in Herdmania is guarded by:
   (a) 4 Lips

(b) 3 Lips

(c) 2 Lips

(d) 1 Lips

6. Megascleres occur through out the body in Herdmania except in:

(a) Heart

(b) Liver

(c) Pharynx

(d) Kidney

7. True coelom in Herdmania is greatly reduced due to the development of :

(a) Body wall

(b) Intestine

(c) Atrium

(d) Mesentr

8. Intestine in Herdmania is:

(a) U shaped

(b) V shaped

(c) C shaped

(d) L shaped

9. In urochordates respiration occur through

(a) Test and gill slits

(b) Tes

(c) Gill slits

(d) Branchial basket

Answer

1 (b), 2 (d), 3 (d), 4 (d), 5 (a), 6 (a).7 (c) 8 (a) 9 (a)

3.8 TERMINAL QUESTION ANSWERS

Q - 1 Why the comman name of herdmania is sea squid?

Q- 2 Give the general characters and classification of Urochodata?

Q- 3 Give the systematic position of Herdmania?

Q- 4 Explain why a living organism required food? Describe the process of feeding and digestion in Herdmania?

Q- 5 Describe the external features and habitat of Herdmania?

Q- 7 Give specialized characters of Urochordates and discuss its affinities?

Q-7 Explain the retrogressive metamorphosis in Herdmania larva?

3.9- REFERENCES

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2. Kotpal, R.L 2012.Vertebrata, Rastogi publication Merruth.
3. Nigam,H.C.1983.Zoology of chordates,Vishal publication,Jalandhar
4. Some figure and tax material are adopted from Wikipedia.
5. Some figure and tax material are adopted from Biozoomer.

UNIT: 4 CEPHALOCHORDATA

CONTENTS

4.1 OBJECTIVE

- The study of general characterstics and classification of Cephalochordata.
- To study the body organization and physiology of a Cephalochordate (Aniphioxus)
- To understand the affinities and relationships of cephalochordatawith other groups of animals.

4.2 INTRODUCTION

With about twenty-five species inhabiting shallow tropical and temperate oceans, the Cephalochordata is a very small group of the animal kingdom. Known as lancelets or Amphioxus (from the Greek for "both [ends] pointed," with reference to their shape), cephalochordates are small, eel-like, unprepossessing animals that spend much of their time buried in sand. However, because of their remarkable morphology, they have proved crucial in understanding the morphology and evolution of chordates in general -- including vertebrates.

Cephalochordates have all the typical chordate features. The **dorsal nerve cord** is supported by a muscularized rod, or **notochord**. The pharynx is perforated by over 100 **pharyngeal slits** or "gill slits", which are used to strain food particles out of the water. The musculature of the body is divided up into V-shaped blocks, or **myomeres**, and there is a **post-anal tail**. All of these features are shared with vertebrates. On the other hand, cephalochordates lack features found in most or all true vertebrates: the brain and the sense organs are very small and poorly developed, and there are no true **vertebrae**.

Water is taken in through the mouth, drawn in by the beating of cilia located on the **wheel organ** and a set of ridges lying inside the mouth. The water is first filtered by the **oral cirri**, slender projections that surround the opening of the mouth. It then passes through the gill slits. These gill slits are enclosed by folds of the body wall, the **metapleural folds**, to form a body cavity known as the **atrium**. Food particles in the water are trapped by mucus, while water passes through the slits and out of the atrium through the **atriopore**, located towards the posterior end. The rest of the digestive system is fairly simple: a pouch or **hepatic caecum** secretes digestive enzymes, and actual digestion takes place in a specialized part of the

intestine known as the **iliocolonic ring**. Cephalochordates also have a well-developed circulatory system and a simple excretory system composed of paired **nephridia**. The sexes are separate, and both males and females have multiple paired gonads. Eggs are fertilized externally and develop into free-swimming, fishlike larvae.

Since cephalochordates have no hard parts, their fossil record is extremely sparse. However, fossil cephalochordates have been found in very old rocks indeed, predating the origin of the vertebrates. The famous Middle Cambrian Burgess Shale of British Columbia has yielded a few fossils of *Pikaia*, which appears to be a cephalochordate (although the fossils are still being restudied). More recently, *Yunnanozoon*, from the Early Cambrian of south China, was reported to be a cephalochordate, the earliest known (Chen et al., 1995). These fossils show that the chordate lineage appeared very early in the known history of the animal kingdom, and they strengthen the case for an origin of true vertebrates from a cephalochordate-like ancestor.

Today, Amphioxus may be extremely common in shallow sandy environments: at Discovery Bay, Jamaica, up to five thousand individuals per square meter of sand have been reported. In some parts of the world, Amphioxus is eaten by humans or by domestic animals; they are important food items in some parts of Asia, where they are commercially harvested.

4.3 GENERAL CHARACTERSTICS OF CEPHALOCHORDATA

a) Body is fish -like and is useful for burrowing and swimming.
b) It has a head.
c) It shows a tail.
d) Appendages are absent.
e) Dorsal, caudal and ventral fins are present.
f) Body- wall shows one- cell thick, non-ciliated epidermis, dermis, connective tissue, striated muscle and parietal peritoneum.
g) It has no exoskeleton.
h) Notochord extends from the anterior end to posterior end.
i) Enterocoelic coelom is present, however, it is reduced in the pharyngeal region by atrium.

j) Alimentary canal is long. It includes a large pharynx with many gill-slits. Ciliary mode of feeding is developed.
k) Gills perform respiration.
l) Circulatory system is closed.
m) Heart and respiratory pigments are absent.
n) Hepatic portal system is present.
o) Excretory system shows paired protonephridia with solenocytes.
p) Brain is not present.
q) Two pairs of cerebral and several pairs of spinal nerves are present.
r) Sexes are separate. Gonads are metamerically arranged and are without gonoducts.
s) Asexual reproduction never occurs.
t) Fertilization is external.

4.4 CLASSIFICATION AND SYSTEMATIC POSITION OF CEPHALOCHORDATA

The sub-phylum Cephalochordata includes a single class- Leptocardii, which has single family Branchiostomidae. The family contains only two genera *Branchiostoma* and *Asymmetron.* Pallas described these animals first. He named the Cephalochordates as *Umax lancealatus,* and included this in Mollusca. In 1834, Costa described its chordate features. In 1836, Yarrel named it as *Amphioxus.*Later on few specimens were recognized as *Asymmetron.* Thus, two genera were distinguisghed later.

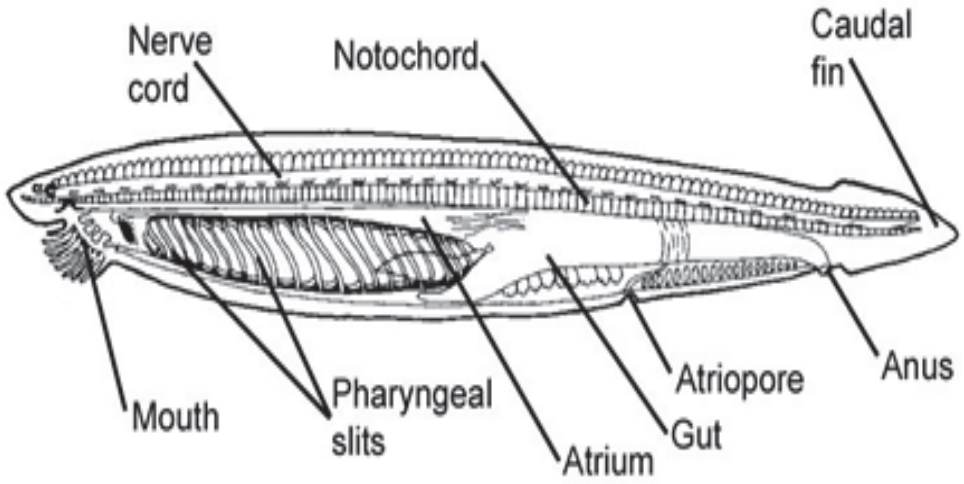

Fig 4.1 Body organization of cephalochordata

The characteristics and body structure of cephalochordates can be described under the following heads:

(a) CHORDATE FEATURES OF CEPHALOCHORDATA (AMPHIOXUS):

i. Presence of dorsal tubural nerve cord.

ii. Presence of a long notochord from anterior end to posterior end on the dorsal side. Because, it extends to the cephalic region, the group is called Cphalochordata.

iii. Gill silts are present in the Pharynx.

iv. Presence of post anal tail.

v . Presence of liver diverticulum.

vi. Development of hepatic portal system.

vii . Presence of myotomes which are useful for locomotion.

viii . Presence of dorsal, caudal and ventral fins.

(b) PRIMITIVE CHARACTERS OF CEPHALOCHORDATA:

i. The excretory system contains protonephridia.

ii. In Chordata, the presence of solenocytes is not reported. But, in *Amphioxus* solenocytes are associated with nephridium.

iii. Absence of heart and kidney.

iv. Absence of paired limbs or paired fins.

v. Absence of distinct head.

vi. Absence of distinct paired sense organs.

vii. Gonads are without gonoducts.

(c) SPECIAL CHARACTERS OFCEPHALOCHORDATA:

i. Because of its ciliary mode of feeding, the pharynx is elaborated with many gill slits. .
ii. Oral hood is well developed for ciliary mode of feeding.
iii. Because of its ciliary mode of feeding the atrium is very well developed.

Thus, *Amphioxus* shows some special characters which are developed because of its ciliary mode feeding.

4.5 CEPHALOCHORDATES, RELATIONSHIP WITH OTHER GROUP OF ANIMALS

Cephalochordates show many close relationship with Urochordata.However, in some points they differ from Urochordates

Similarities:-

i. Presence of gill slits in pharynx.
ii. Presence of endostyle in pharynx.
iii. Presence of ciliry mode of feeding.
iv. Presence of atrium.

Differences:

i. Absence of test in Cephalochordates.
ii. Absence of distinct heart in Cephalochordates.
iii. Presence of notoçhord and nervecord in the adults in Cephalochordates
iv. Presence of myotomes in the adult in Cephalochordates

In this way Cephalochordates differ with Urochordates.

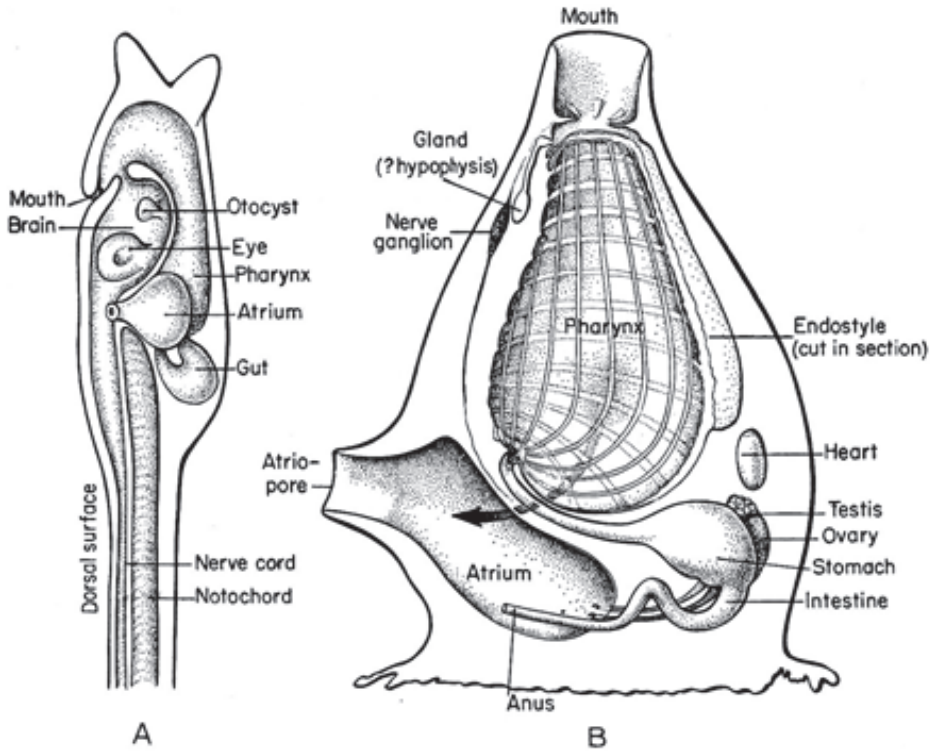

Fig: 4.2 Comparision of body organization of Cephalochordata and Urochordata

(B) Cephalochordates show some invertebrate features

i. Presence of paired nephridia like annelids.
ii. Presence of flame cells like Helminths.
iii. Presence of soft body and slug like appearance like molluscs.

By considering the above facts we come to a conclusion that:-

Amphioxus is a chordate animal. It is a degenerate jawless chordate. It mainly shows chordate features and differs from urochordates in some aspects. Hence, it is separated and kept in a separate sub phylum called Cephalochordate.

4.6 GENERAL STUDY OF BRANCHISTOMA OR AMPHIOXUS

Systematic position

Phylum Chordate
Group Acrania
Subphylum Cephalochordate
Class Leptocardii
Family Branchiostoma (Amphioxus)

Branchiostoma is one of the few living genera of lancelets (order Amphioxiformes)

Amphioxus is a small marine animal found widely in the coastal waters of the warmer parts of the world and less commonly in temperate waters. It is seldom more than 8 cm (3 inches) long and resembles small, slender fishes without eyes or definite heads.

Amphioxus spends much of its time buried in gravel or mud on the ocean bottom, although they are able to swim. When feeding, they let the anterior part of the body project from the surface of the gravel so that they can filter food particles from water passing through their gill slits. At night they often swim near the bottom. They burrow into sand using rapid movements of the body, which is tapered at both ends and is covered by a sheath (the cuticle).

The animals swim by contracting the muscle blocks, or myotomes, that run from end to end on each side of the body. The blocks on each side are staggered, producing a side-to-side movement of the body when swimming. Amphioxus is not buoyant, and they sink quickly when they stop swimming. A dorsal fin runs along the entire back, becomes a caudal fin around the tip of the tail, and then continues as a ventral fin; there are no paired fins.

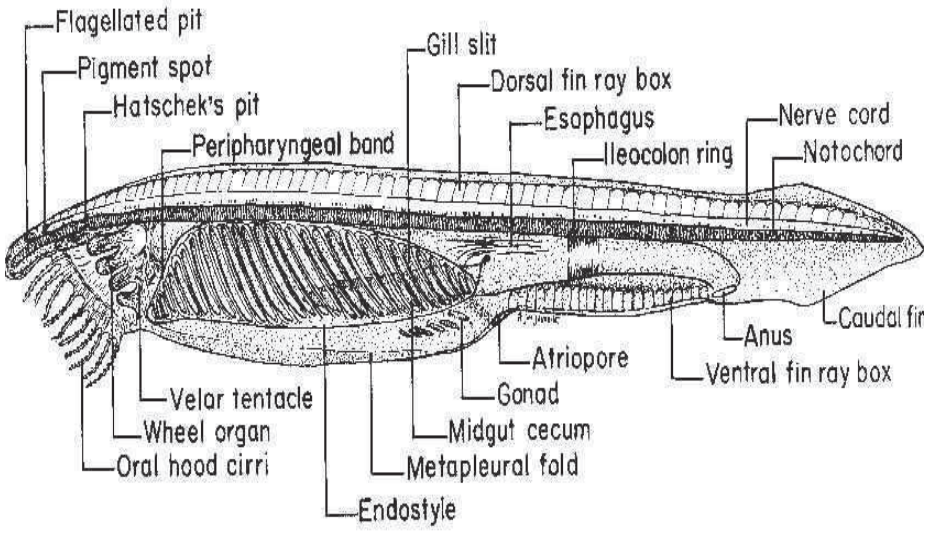

Fig 4.3 Structure of Amphioxus

The notochord runs through the body from tip to tip, providing a central support. A slight bulge distinguishes the anterior end of the nerve cord. Although there is no brain or cranium, growing evidence suggests that the vertebrate brain evolved from a portion of the nerve cord in a lancet like ancestor. Blood flows forward along the ventral side and backward along the dorsal side, but there is no distinct heart.

The oral cavity of amphioxi is furnished with a hood whose edges are lined with cirri; these are fringer like structures that form a coarse filter to screen out particles too large to be consumed. Water is directed through the small mouth into the pharynx by the action of cilia on the gill slits. Food particles in the passing water are caught by the mucous lining of the gill basket and pass into the gut, where they are exposed to the action of enzymes. Unlike other chordates, Amphioxus is capable of a digestive process called phagocytosis, in which food particles are enveloped by individual cells.

Above the pharynx is the excretory system made up of the nephridia, which opens into an excretory canal leading to the atrium. The endostyle corresponds to the thyroid in vertebrates, since it seems to produce iodinated, tyrosine molecules, which may function as regulatory substances, much like hormones.

Digestive system

As mentioned above, Amphioxus have oral *cirri*, which are thin tentacle-like strands that hang in front of the mouth and act as sensory devices and as a filter for the water passing into the body.

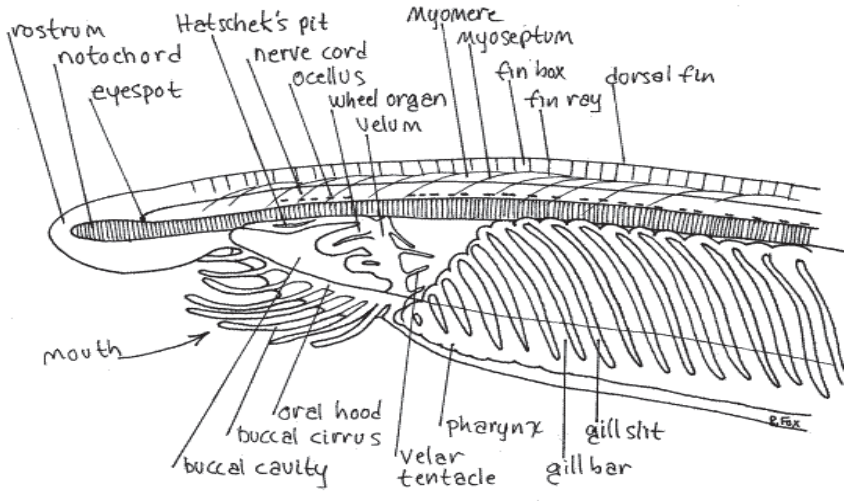

Fig 4.4 Anterior end of Amphioxus body

Water passes from the mouth into the large pharynx, which is lined by numerous gill-slits. The ventral surface of the pharynx contains a groove; called the endostyle.Which is connected to a structure known as Hatschek's pit, produces a film of mucus. Ciliary action pushes the mucus in a film over the surface of the gill slits, trapping suspended food particles as it does so. The mucus is collected in a second, dorsal, groove, and passed back to the rest of the digestive tract. Having passed through the gill slits, the water enters an atrium surrounding the pharynx, and then exits the body via the *atriopore*.

Both adults and larvae exhibit a "cough" reflex to clear the mouth or throat of debris or items too large to swallow. In larvae the action is mediated by the pharyngial muscles while in the adult animal it is accomplished by atrial contraction.

The remainder of the digestive system consists of a simple tube running from the pharynx to the anus. The hepatic caecum, a single blind-ending caecum, branches off from the underside of the gut, with a lining able to phagocytize the food particles, a feature not found in vertebrates. Although it performs many functions of a liver, it is not considered a true liver but a homolog of the vertebrate liver.

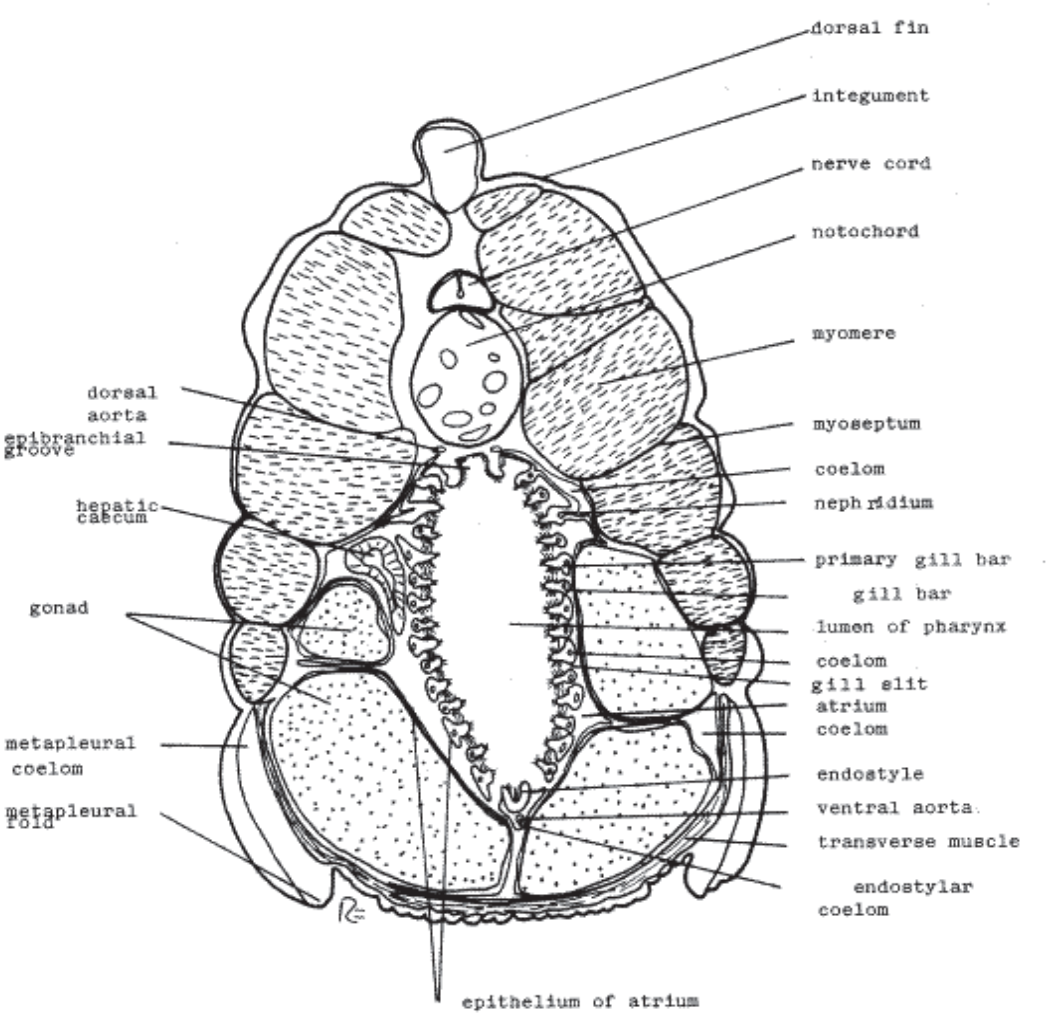

Fig 4.5 T.S of Amphioxus through Pharynx

Nervous system

Amphioxus possesses a hollow nerve cord running along the anterio- posterior end of the body.
Unlike vertebrates, the dorsal nerve cord is not protected by bone but by a simple notochord made up of a cylinder of cells that are closely packed to form a toughened rod. The lancelet notochord, unlike the vertebrate spine, extends into the head. This gives the subphylum its name (*cephalo-* meaning 'relating to the head'). The nerve cord is only slightly larger in the head region than in the rest of the body.

Respiratory System

Spacial respiratory organs are lacking.The pharyngeal wall of Amphioxus is richly vascular and water current enters the pharyngeal cavity. The blood flows so close to the surface that some exchange between CO_2 of blood and O_2 of water can easily occur .But there is no capillary network in gill bars. Further the blood lacks a respiratory pigment .It is probable that most gaseous exchange occurs through superficial areas such as fins, metapleural folds and atrial wall containing lymph spaces.

REPRODUCTION IN AMPHIOXUS

Amphioxus is a unisexual animal. But sexual dimorphism is absent. *Amphioxus* shows 26 pairs of Gonads. They are present from 25th myotomal segments to 51. Gonads have no ducts.

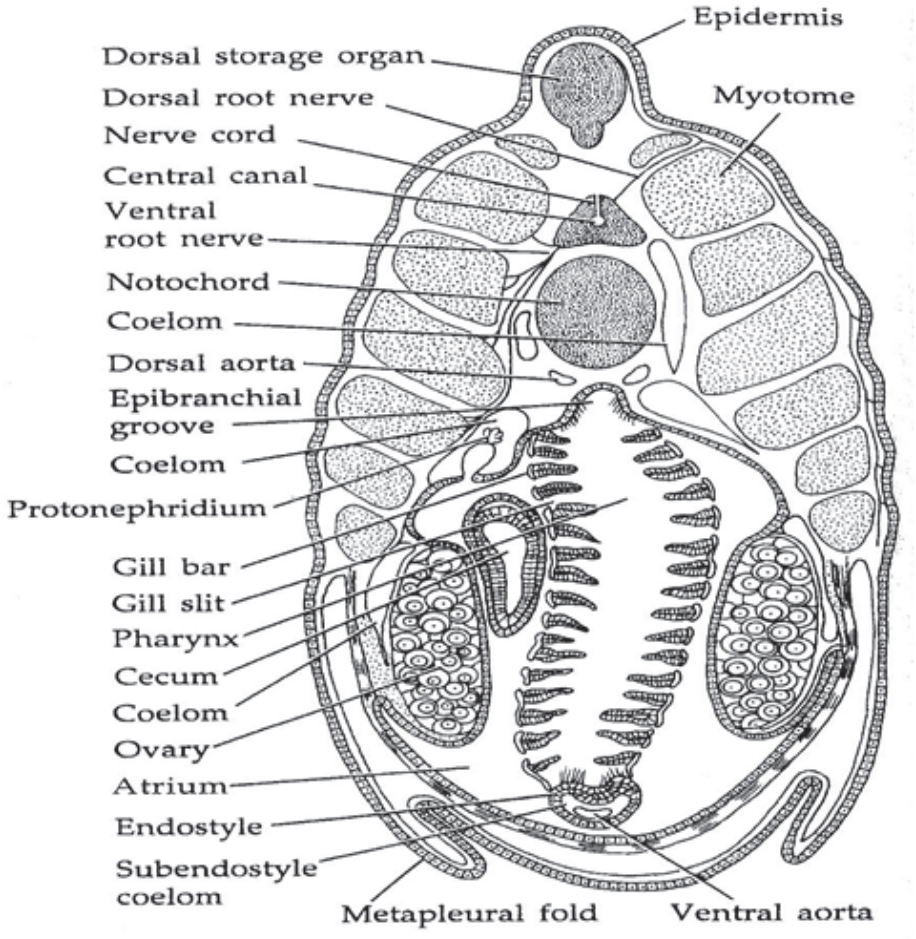

Fig 4.6 T.S Amphioxus through Gonads

When mature the overlapping tissue of the gonad will rupture and the gametes are Iibreted into atrium of Amphioxus. -They will come out into the water through the atriopore.

Gametes of *Amphioxus*:

The mature male sex cell called sermatozoan. It is 15 to 20 cm in length and shows three regions namely head, middle piece and tail.

On the head acrosome is present. Head shows a big nucleus. Around the nucleus thin sheet of cytoplasm is present.The middle piece is small with mitochondrial matrix called nebenkeron. The tail is long and helps in movement.

The mature female sex cell is ovum. It is small and 0.12 mm in diameter. It is a **microlecithal egg**. The cytoplasm around the nucleus will show yolk. In the peripheral cytoplasm yolk is absent. It is granular and is called carticoplasm. The plasma membrane surrounds the cytoplasm. Around this is a mucopolysaccharide membrane is present. It is called vettaline membrance. In between these two layers perivitelline space is present. The nucleus is present towards the animal pole, where as the opposite pole is called vegetal pole. The vegetal pole becomes posterio dorsal side of the embryo. The Animal pole becomes antero-ventral side of the embryo. Hence a gradient polarity is established in the egg.

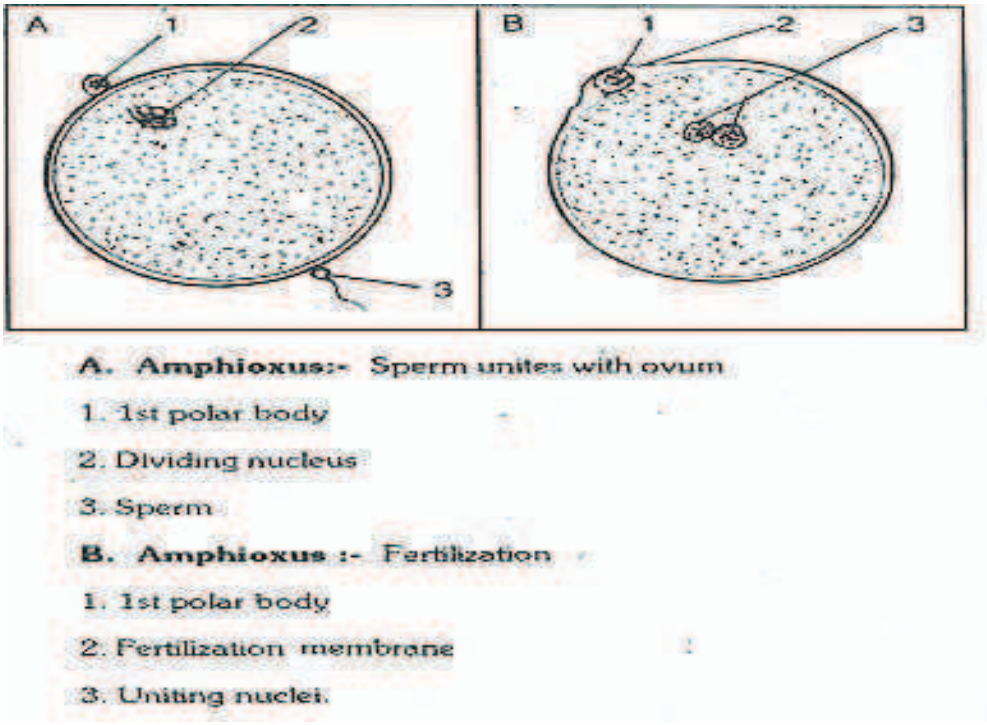

Fig 4.7 Egg or Ovum in Amphioxus

FERTILISATION: As soon as the egg comes in contact with the water the vitelline membrane wilI separates from the plasma membrane.

A number of sperms surround the egg, but only one makes entry through the contents of the egg from the vegetal pole. At this time a number of changes take place in the corticoplasm. Now membranes are formed which unite with vitelline membrane. This is called fertilisation.

4.7 SUMMARY

Cephalochordata (or lancelets, traditionally known as amphioxus, plural amphioxi) is a subphylum of marine invertebrates of the phylum Chordata. They are usually found in shallow parts of temperate or tropical seas. As with all chordates—a group that includes tunicates (subphylum Urochordata), hagfish (class Agnatha), and all vertebrates (class Vertebrata)—cephalochordates have a notochord, a hollow dorsal nerve cord, and pharyngeal slits (or pharyngeal pouches). Cephalochordates retain the notochord throughout their lives, unlike tunicates and vertebrates that have the notochord only during early (embryonic, larval) stages. Unlike vertebrates, cephalochordates and tunicates lack a backbone or vertebral column.

The notochord of cephalochordata, unlike the vertebrate spine, extends into the head. This gives the subphylum its name (cephalo- meaning "relating to the head"). Lancelets are blade-shaped (tapered at both ends), yielding the name amphioxus, which comes from the Greek for "both (ends) pointed."

With only about 30 species, it would be easy to overlook this subphylum and its importance. Yet, in Asia, lancelets are harvested commercially for food that is eaten by both humans and domesticated animals, and they are an important object of study in zoology as they provide evidence about the origins of the vertebrates. Cephalochordates also play a key role in food chains, sometimes they are found in thousands per square meter of sand.

There are only two genera of cephalochordates recognized—Branchiostoma (originally Amphioxus, about 23 species) and Asymmetron (about six species). The common name lancelet, or amphioxus, is generally used for all cephalochordates.

4. 8 SELF ASSESSMENT QUESTIONS

1. In Cephalochordate, gill slits open into:
   (a) Pharyanx
   (b) Atrium
   (c) Coelom
   (d) Herat

2. Amphioxus is _____
   a) Planktonic
   b) Pelagic
   c) Sedentary
   d) Burrowing animal.

3. The thermorecepter in Branchiostoma is:
   (a) Eye spot
   (b) Cephelic pigments
   (c) Infundibular orgen
   (d)Kollickers pit

4. Coelom in amphioxus is:
   (a)Enterocoelic in origin
   (b) Schizocoelic in origin
   (c) Pseuodocoelom
   (d)Absent altogether

5. Atriumin Branchiostoma is formed by:
   (a) Folding of endoderm
   (b) Folding of mesoderm
   (c) Folding of ectoderm
   (d) Apair of Meta pleural folds

6 In Branchiostoma gill slits open:
   (a) Into the coelom
   (b) Directly to the extent
   (c) Into the atrium
   (d) Into the pharynx

7. Mouth in Branchistoma is bordered by:
   (a) Oral cirri
   (b) Oral hood
   (c) Oral frill
   (d) Oral tentacles

8. Wheel organ is a part of:
   (a) Mouth
   (b) Oral hood
   (c) Velum
   (d) Pharyanx

9. Members of subphylum cephalochordate live in:
   (a)Marine and shallow water
   (b) Marine and deep water
   (c) Swamps
   (d) Fresh water lakes

10. In cephalochordate respiration take place
   (a) Thourhg gills
   (b) Thourgh nostrils
   (c) Thourgh general body surface
   (d) Thourgh lungs

Answers

1 (b) 2 (c) 3(a) 4 (a) 5 (d) 6 (c) 7 (b) 8 (b) 9 (a) 10 (c)

4.9 TERMINAL QUESTION ANSWERS

1. Give general characters of Cephalochordata.

2. Describe habit, habitat, and distribution and give morphology of branchiostoma.

3. Describe the reproductive system of Amphioxus.

Short Note:

1. Digestive system of amphioxus

2. Nervous system of amphioxus

3. Respiratory system of amphioxus

4.10 REFERENCES

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4. Some figure and tax material are adopted from Wikipedia.
5. Some figure and tax material are adopted from Biozoom

UNIT: 5 CYCLOSTOMATA (AGNATHA)

CONTENTS

5.1 OBJECTIVE

- To understand the systematic and functional morphology of various groups of Cyclostomata.
- To study their affinities and adaptations to different modes of life.
- To describe and explain the basic biology, evolution and development system of Cyclostomata.
- To impart knowledge in comparative anatomy and development of Cyclostomata.
- To understand the ecological terms.

5.2- INTRODUCTION

Cyclostomata is a group of chordates that comprises the living jawless fishes: the lampreys and hagfishes. Both groups have round mouths that lack jaws but have retractable horny teeth. The name Cyclostomata means "round mouths".Their mouths cannot close due to the lack of a jaw, so they have to constantly cycle water through the mouth.

5.3 GENERAL CHARACTERS OF CYCLOSTOMATA

1. Cyclostomes are jawless primitive vertebrates. They may be marine or fresh-water. They include hag fishes and lampreys (fig 5.1).

(a)

(b)

Fig 5.1 (a) Hag Fish (b) Lamprey

2. The body is long, eel like. It has a trunk and a compressed tail.
3. Paired fins are absent. Median fin is supported by cartilaginous fin-rays.
4. The skin i.e soft and smooth. It is slimy. It is scale less.
5. Z- shaped myomeres are present in the trunk and tail Protractor and retracstor muscles Move the tongue.
6. In this group a true coelome is seen.
7. These vertebrates do not have jaws, hence called Agnatha.
8. The mouth is circular. It works like a sucker and is surrounded by tentacles.
9. Tongue bears teeth.
10. Stomach is absent and oesophagus leads into the intestine.

11. Endoskeleton is present.

12. Skull is simple and primitive.

13. Notochord presists throughout life.

14. Vertebrae are represented by neural arches, around the notochord.

15. Five to sixteen pairs of gills are present in sac like pouches

16. The heart is two chambered. Sinus venousus is present, but conus arterescsus is absent.

17. Blood contains leucocytes and Irregular nucleated erythrocytes..

18. Brain is seen.

19. Ten pairs or less number of cranial nerves are present.

20. Nasal sac is single and median.

21. Lateral line sense organ is present.

22. Excretory system includes a pair of mesonephric kidneys.

23. Sexes are separate.

24. Gonad is single and without a gonoduct.

25. Development may be direct or with a long larval stage.

5.4 CLASSIFICATION

The class Cyclostomata is divided into two orders:

1) Petromyzontia and (2) Myxinoidea

Order 1. Petromyzontia

1) This includes Lampreys.

2) The buccal funnel is suctorial and shows horny teeth.

3) The mouth is present in the buccal funnel.

4) The nasal sac is dorsal. It has no connection with the pharynx.

5) Eyes are functional.

6) Seven pairs of gill slits are present.

7) A well-developed dorsal fin is present.

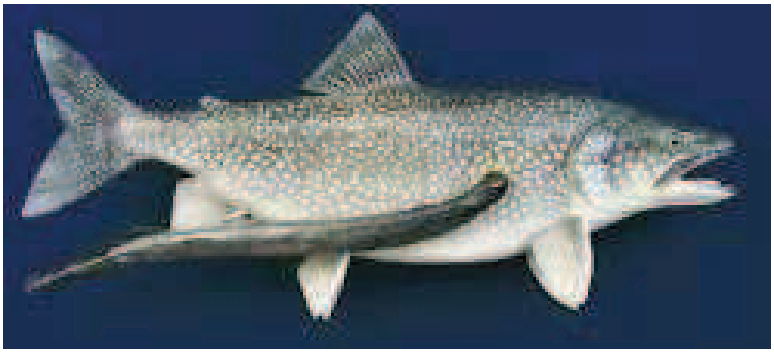
8) Branchial basket is complete.

9) Brain is well developed.

10) Pineal eye is well developed.

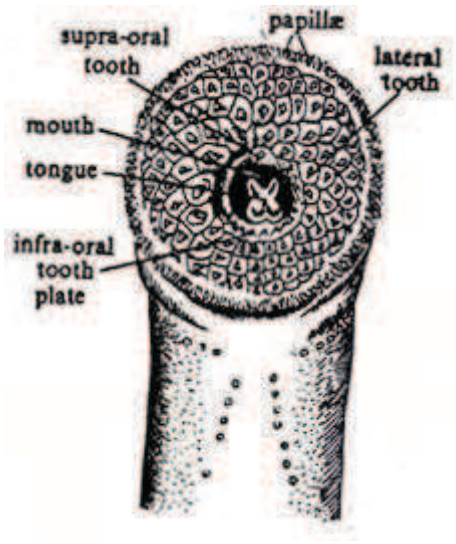
11) Ear has two semicircular canals.

Ex: 1. Petromyzon (Sea-lamprey).



(a)

(b)



(C)

Fig.5.2 (a) Lamprey on lake trout (b) Sea Lamprey(c) Suctorial mouth of Lamprey

Order 2: Myxinoidea

1) It includes the hag-fishes or slime eels.

2) Buccal funnel is absent.

3) The nasal sac opens into pharynx through a canal.

4) Eyes are vestigial.

5) Dorsal fin is absent or very small.

6) Branchial basket is poorly developed.

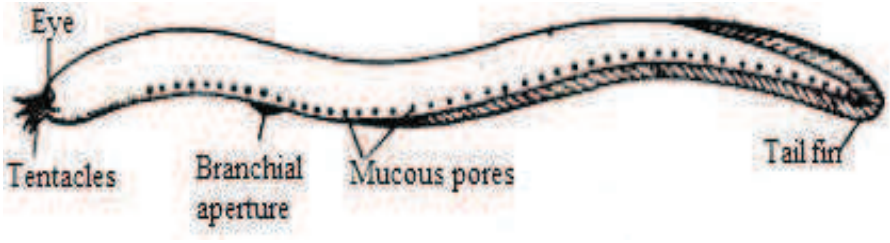


Fig 5.3 Myxine sp.Lateral view

7) Brain is primitive.

8) Pineal eye is reduced.

9) Ear has only one semicircular canal.

10) The hag-fishes are all marine.

Ex: 1. Myxine glutinosa Hag-fish or slime eel). 2. Eptatretus (Bdellostoma)

5.5 GENERAL STUDY OF PETROMYZON

General study of Petromyzon

Systematic position

Phylum Chordata

Sub phylum Vertebrata

Group Agnatha

Class Cyclostomata

Order Petromyzontiformes

Family Petromyzontdae

Type Petromyzon (Lamprey**)**

External Feature:

Lampreys are eel-like in appearance, but have a soft, cartilaginous skeleton. They lack paired fins but have well developed dorsal and ventral finfolds. In the adult, the jaws are so rudimentary that apparently they are wanting; the mouth is a longitudinal slit when closed, but forms an elliptical disc at the tip of the snout when open, and is armed with many horny, hooked teeth arranged in numerous (11 to 12) rows, the innermost the largest. There are two dorsal finfolds, and seven open gill slits on each side. The sea lamprey (the only member of its group known from our salt waters) can hardly be mistaken from any other fish its eel-like appearance coupled with two dorsal fins and the jawless mouth loeate it at a glance.

Colour:

Small specimens (whether on their way downstream or in salt water) are white below and uniformly colored above, usually described as blackish blue, or as lead colored, and more or less silvery. But large specimens usually are olive brown above, or of varying shades of yellow-brown, green, red, or blue, mottled with a darker shade of the same color, or sometimes nearly black if the dark patches are confluent. The lower surface is whitish, gray, or of a pale shade of the same hue as the ground color of the back. During breeding season, the landlocked form takes on more brilliant hues, with the ground tint turning bright yellow.

Size:

The length at the time of transformation from the larval stage is about 4 to 8 inches (100-200 mm.). Sexually mature individuals, taken [page 13] in American rivers, average 2 to 2½ feet long, up to a maximum of about 3 feet. One of 33 inches weighed 2¼ pounds.

Habit and Habitats:

It has been known since a longtime that the sea lamprey breeds in freshwater. However, it does not enter all the streams within its range indiscriminately. As an illustration, we may cite outer Nova Scotia and the Bay of Fundy, where lampreys run in the St. Marys, Sackville, Annapolis, Shubenacadie, Petit Codiac, and St. Johns Rivers, but not in the Moser or Apple Rivers, although these last also are "salmon" rivers. Their requirements are a gravelly bottom in rapid water for their spawning beds, with muddy or sandy bottom in quiet water nearby, for the larvae.

STRUCTURAL FEATURES

1. External Gill Slits - openings that lead to the internal gills that are used to extract oxygen from the water. Lampreys have seven distinctive gill slits (fig. 5.4).

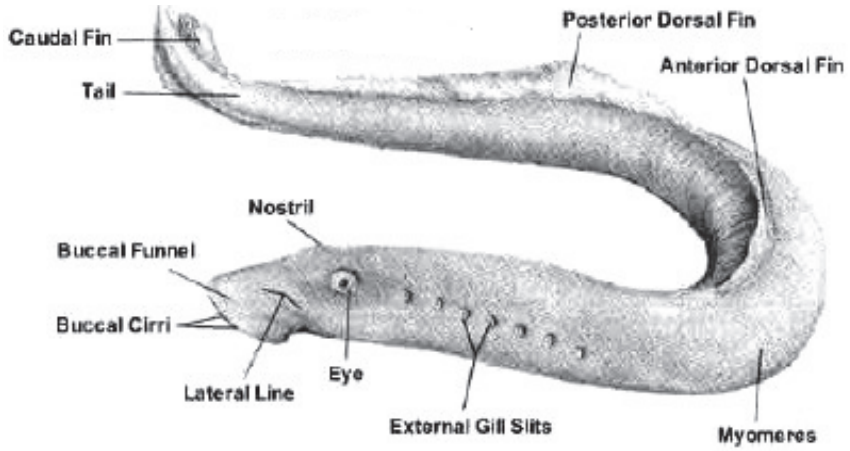


Fig 5.4 Adult Lamprey

2. Buccal Funnel - is the beginning of the mouth cavity. It contains numerous teeth in the adult lamprey. It is surrounded and supported by the oral disc.

3. Buccal Papillae - finger-like projections that surround the buccal funnel.

4. Lateral Line System - a system consisting of lines of pores that sense water currents, water pressure changes, and movements and vibrations in the water. The visible external pores of the lateral line system lead to an internal canal, which connect with specialized sensory cells. This system is believed to be related to the sense of hearing in other vertebrates.

5. Median Nostril - The median nostril is a primitive feature unique to the lamprey. Other vertebrate animals have paired nostrils. The nostril is responsible for detecting scents and leads to a nasal tube in the dorsal region of the head. A lamprey can "smell" by perceiving chemicals in the water. These scent particles can be detected from great distances. Chemical scents enter the medial nostril, pass through the nasal tube triggering the olfactory nerve cells along the way, and send electrical signals to the brain via the olfactory nerve.

. 6. Pineal Organ - The pineal organ is located under the skin immediately posterior to the medial nostril. Evidence of its presence is shown by a generalized round bump on the dorsal side of the head. In the lamprey, the pineal organ is sometimes referred to as a "third eye" due to its role in perceiving light and dark. The pineal organ contains a light sensitive retina that does not interpret visual images.

7. Eye - The eye is a sensory organ responsible for receiving visual input. It leads to the optic nerve, which sends visual impulses to the brain. In the brain the images are deciphered. The adult lamprey

eye is structurally very similar to the eyes of other vertebrates consisting of a cornea, iris, lens and retina. There are no eyelids present in the lamprey.

8. Anterior Dorsal Fin - A fin used to maintain an upright orientation in the water while moving about.

9. Posterior Dorsal Fin - This fin has the same function as the anterior dorsal fin.

10. Caudal Fin - A powerful fin used to thrust the lamprey's body through the water.

11. Cloaca - The common opening of the urinary and reproductive systems. It receives waste from the kidneys and fluids from the reproductive organs and transfers them to the external environment via the opening of the cloaca. The urogenital papilla is a protrusion that may be extending from the cloaca.

12. Anus - The anus is located immediately anterior to the cloaca. It is an extension of the intestine through which solid waste is expelled from the body.

The Digestive System

The digestive system consists of the alimentary canal, which runs from the mouth to the anus. Food enters the food enters the mouth and moves through the pharynx into the esophagus. The adult lamprey is an ectoparasite and its food is in the form of fish blood.A lamprey does not have a stomach. Rather, food passes directly from the esophagus to the intestine, which absorbs the bulk of the nutrients. The intestine becomes the site of the emulsification, digestion, and absorption of nutrients. The latter portionof the intestine digests bacteria, reabsorbs water, and forms feces. The last section of the intestine narrows to form an exit called the anus. The resulting solid wastes leave the body at this point.

Nervous system

Lampreys have a primitive nervous system, the brain structure is fairly simple compared to other vertebrate animals.System consists of the brain and a hollow spinal cord–Situated above the alimentary canal. –Vertebrate nerve cord and brain contain a cerebrospinal fluid which contains mineral salts and traces of protein and sugar. The fluid helps to support the nervous tissue and probably plays some part in its nutrition.The nerve fibers are not covered by the myelin sheath (a

fatty insulating layer) found in all higher vertebrates–Therefore nervous conduction is slow. The complex nervous connections found in higher forms are impossible in these early vertebrates**.**

CirculatorySystem:

Blood flows through a series of vessels to supply oxygen and nutrients to the body and to remove carbon dioxide and other wastes.–Arteries and arterioles carry blood away from the heart–Veins and venules carry blood back towards the heart–Capillaries are the smallest vessels where the gases are exchanged with the cells of the body

RespiratorySystems:

A lamprey "breathes" by extracting the oxygen present in the water in which it lives.Within the respiratory tube are seven gill pouches, each containing the finer feather-like gill lamellae. The gill lamellae increase the surface area of the respiratory structures and contain the small capillary beds that extract oxygen Problem, when a lamprey is feeding and attached to a fish the mouth serves as an attachment organs, it is no longer available for use in respiration. Under this situation Water can be drawn directly into the respiratory tube through the external gill slits. Muscular contractions change the volume of the respiratory tube and thus control the movement of water over the gill lamellae.

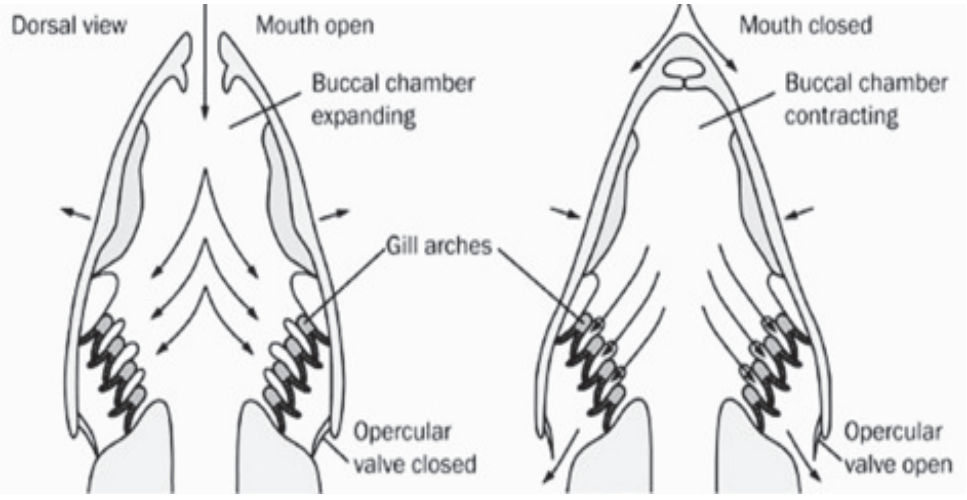


Fig 5.5 Mechanism of respiration in lamprey

Excretory System

Kidney: filters out waste from the blood–Ions, water and other nitrogenous wastes– Responsible for maintaining osmoregulation.The balance between the salts in the body and the salts in the environment. Kidneys excrete extremely dilute urine to maintain the ionic balance in the body. Kidneys excrete highly concentrated urine. Lampreys rely on the gills to get rid the body of excess salt.

1. Life Cycle & Reproduction:

Lampreys are Anadromous or fresh water, eel-shaped jawless fishes. They can be readily recognized by the large, rounded sucker which surrounds their mouth and by their single "nostril" on the top of their head. The skin of Lamprey is entirely naked ans slimy and their seven gill openings extend behind the eyes. Whether marine or fresh water, Lampreys always spaw and lay eggs in brooks and rivers. During most of their life (about
seven years), they are larval then theyundergo a metamorphose and become an adult.

Anadromous lampreys living in freshwater, when adult returns to the sea, where they become mature and live there for one or two years. Then they return to rivers, reproduce and generally die.

Lamprey eggs hatch into small larvae, known as ammocoetes, which are not predators at all; they lack the sucker mouths of the adults, and feed by producing strands of mucus and trapping food particles. The ammocoetes stage may last up to seven years before its metamorphosis into an adult. Adult lampreys live for a year or two before spawning, and then die soon afterwards.

CONTROL OF LAMPREYS:

Since lampreys are parasitic,they are harmfull to the Control efforts, including electric current, chemical lampricides have met with varied success. The control programs are carried out under the Great Lakes Fisheries Commission, a joint Canada–U.S. body, specifically by the agents of

the Fisheries and Oceans Canada and the United States Fish and Wildlife Service.Therefore efforts are being made to control them.

Genetic researchers have mapped the sea lamprey's genome in the hope of finding out more about evolution; scientists trying to eliminate the Great Lakes problem are coordinating with these genetic scientists, hoping to find out more about its immune system and fitting it into its place in the phylogenetic tree. Several scientists in this field work directly for Fisheries and Oceans Canada or the United States Fish and Wildlife Service.

Researchers from Michigan State University have teamed up with others from the Universities of Minnesota, Guelph, and Wisconsin, as well as many others in a massive research effort into newly synthesized pheromones. These are believed to have independent influences on the sea lamprey behavior. One pheromone serves a migratory function in that odor emitted from larvae are thought to lure maturing adults into streams with suitable spawning habitat. A sex pheromone emitted from males is capable of luring female’s long distances to very specific locations. These two pheromones are actually both several different compounds thought to elicit different behaviors that collectively influence the lamprey to exhibit migratory or spawning behaviors. Effort is being made to characterize the function of each pheromone, each part of each pheromone, and if they can be used in a targeted effort at environmentally friendly lamprey control. Despite millions of dollars put into research, however, the most effective control measures are still being undertaken by control agents of state and federal agencies, but involve the somewhat publicly unacceptable application of TFM into rivers.

Another technique used in the prevention of lamprey population growth is the use of barriers in major reproduction streams of high value to the lamprey. The purpose of the barriers is to block their upstream migration to reduce reproduction. The issue with these barriers is that other aquatic species are also inhibited by this barrier. Fish that use tributaries are impeded from traveling upstream to spawn. To account for this, barriers have been altered and designed to allow the passage of most fish species but still impede others.

Possible relationships

This taxon is often included in the paraphyletic superclass Agnatha, which also includes several groups of extinct armored fishes called ostracoderms. Most fossil agnathans, such as galeaspids, thelodonts, and osteostracans, are more closely related to vertebrates with jaws (called gnathostomes) than to cyclostomes. Cyclostomes seem to have split off before the evolution of dentine and bone, which are present in many fossil agnathans, including conodonts.

Biologists disagree about whether cyclostomes are a clade. The "vertebrate hypothesis" holds that lampreys are more closely related to gnathostomes than they are to the hagfish. The "cyclostome hypothesis", on the other hand, holds that lampreys and hagfishes are more closely related, making cyclostomata monophyletic.

Most studies based on anatomy have supported the vertebrate hypothesis, while most molecular phylogenies have supported the cyclostome hypothesis.

There are exceptions in both cases, however. Similarities in the cartilage and muscles of the tongue apparatus also provide evidence of sister-group relationship between lampreys and hagfishes. And at least one molecular phylogeny has supported the vertebrate hypothesis. The embryonic development of hagfishes was once held to be drastically different from that of lampreys and gnathostomes, but recent evidence suggests that it is more similar than previously thought, which may remove an obstacle to the cyclostome hypothesis. There is at present no consensus on the correct topology.

Differences and similarities between Myxine and Petromyzon

- Hagfish have no spinal cord, while lamprey's have.
- Lamprey can survive in both salt water and in freshwater, but hagfish cannot
- While lampreys feed on the living, hagfish feed on the dead.

Both hagfishes and lampreys have just one gonad, but this is due different reasons. In hagfishes it is because only a single gonad is developed during their ontogeny, while it is achieved through the fusion of gonads in lampreys.

Unlike jawed vertebrates, which has three semicircular canals in each inner ear, lampreys have only two and hagfishes just one. But the semicircular canal of hagfishes contains both stereocilia and a second class of hair cells, apparently a derived trait, whereas lampreys and other vertebrates have stereocilia only. Because the inner ear of hagfishes has two forms of sensory ampullae, their single semicircular canal is assumed to be a result of two semicircular canals that have merged into just one.

The hagfish blood is isotonic with seawater, while lampreys appear to use the same gill-based mechanisms of osmoregulation as marine teleosts. Yet the same mechanisms are apparent in the mitochondria-rich cells in the gill epithelia of hagfishes, but never develop the ability to regulate the blood's salinity, even if they are capable of regulating the ionic concentration of Ca and Mg ions.

The lamprey intestine has a typhlosole that increases the inner surface like the spiral valve does in some jawed vertebrates. The spiral valve in the latter develops by twisting the whole gut, while the lamprey typhlosole is confined to the mucous membrane of the intestines. The mucous membranes of hagfishes have a primitive typhlosole in the form of permanent zigzag ridges. This trait could be a primitive one, since it is also found in some sea squirts such as *Ciona*. The intestinal epiphelia of lampreys also have ciliated cells, which have not been detected in hagfishes. Because ciliated intestines are also found in Chondrostei, lungfishes and the early stages of some teleosts, it is considered a primitive condition that has been lost in hagfishes.

5.6 SUMMARY

Cyclostomata comprises two families of living jawless fishes: hagfishes (Myxinidae, 44 species) and lampreys (Petromyzonidae, 41 species). Morphological analyses have favored the closer relationship of lampreys to jawed vertebrates (gnathostomes) than to hagfishes. However, most of the recent molecular phylogenetic analyses have supported a hagfish-lamprey relationship. The estimated divergence time for hagfishes and lampreys among several studies averages 482 million years ago (Ma), but varies (520-432 Ma) depending mostly on the assumed timing of the cyclostome-gnathostome divergence. Nonetheless, there is agreement that hagfish and lamprey lineages diverged relatively shortly (within 100 million years) after the divergence of cyclostomes and gnathostomes.

5.7 GLOSSARY

Accessory heart: a valved sac usually located in the caudal region and powered by contraction of skeletal muscle of the fish that helps move venous blood back to the heart. Hagfish have several accessory hearts one of which is comprised of actual cardiac muscle.

Aerobic: oxygen requiring

Agnatha: a taxonomic designation. Asuperclass under subphylum vetebrata, the agnathans are lampreys and hagfish. They are jawless and are the most primitive of living fishes.

Affinity: with reference to hemoglobin, this is the ease with which the hb loads oxygen. Hb with a high affinity for oxygen will load at a lower partial pressure while hb with a lower affinity loads at a higher partial pressure.

Alimentary canal: The entire digestive tube (mouth, esophagus, stomach and intestine) collectively.

Anabolism: Constructive metabolism, the building up of more complex organic molecules from simpler ones.

Anoxic: without oxygen.

Aquaculture: the growing of aquatic organisms for human needs, this includes fish farming.

ATP (Adenosine Triphosophate): This is a high energy compound that serves the source of power for cellular work.

Bolus: A small, lump or mass of substance, *e.g*. A meal of partially digested food in the digestive tract.

Buccal cavity: The mouth cavity ahead of the gills, the space behind the gills is the opercular cavity.

Capillary: The smallest blood vessels, just big enough for passage of red blood cells. It is in the capillaries that products diffuse in and out of blood.

Carbohydrase: An enzyme that breaks down starches in the gut into simple sugars for absorbtion.

Catabolism: Destructive metabolism, the breakdown of organic molecules into simpler forms.

Chondricthyan: A member of the class chondricthyes, cartilagenous fishes. Living fish in the class are the sharks and rays.

Covalent: The strong chemical bond created by electron sharing.

Diurnal: Over the course of a day, daily.

Elasmobranchs: A taxonomic designation. The subclass of sharks and rays under class chondricthyes.

Embolism: Blockage of a blood vessel by a bit of foreign matter (bubble, blood clot).

Emulsify: To make into an emulsion, a finely divided suspension of an oil in an aqueous mixture.

Endocrine: Secreting "into", typically from glandular tissue into the blood.

Erythrocyte: Red blood cell's (RBC), the primary function of which is to contain hemoglobin that carries oxygen in blood.

Estivation: An extended period of slowed metabolism.

Euryhaline: A wide tolerance for environmental salinity, in other words, the ability to move from fresh water to salt water and back again.

Exocrine: Secreting "out of", typically from glandular tissue into the intestine.

Fecundity: Number of offspring. A highly fecund fish produces a large number of offspring.

Filament: Part of the gill, a paired series of filaments branch off each gill arch, each filament bears many lamellae where actual blood/water exchange occurs. Filaments are sometimes termed "primary lamellae".

Gonadotropin: A pituitary hormone that stimulates the gonads.

Glycogen: An insoluble carbohydrate formed by animals from glucose for storage of energy in liver and muscles, "animal starch".

Glycolysis: The anaerobic pathway for the phosphorylation of ADP to ATP using glucose as an energy source. Glucose is transformed into pyruvate generating two ATP's. Under aerobic conditions, pyruvate can flow through the Krebs cycle with production of 12 more ATP's. In the absence of oxygen, pyruvate is converted to lactate.

Glomeruli: (singular, glomerulus) the bundle of porous capillaries in vertebrate kidneys that pass water (and sugar and salts) into the kidney tubule to begin urine flow.

Glomerular filtrate: The water and molecules (salts, glucose and small protein molecules) that pass through the glomerular capillaries into the kidney tubule.

Gross: In the context of anatomy this refers to the whole, unmagnified view.

Haldane effect: Named for a British physician, this describes the fact that deoxygenated hb is a better proton acceptor than the oxygenated form. When hb becomes oxygenated it releases hydronium ions driving $h^+ + hco_3^-$ toward $co_2 + h_2o$.

Hematocrit: A measurement of the volume of the cells in blood. It is determined by centrifuging a small tube of whole blood until the cells separate from the plasma. The packed cell volume is expressed as a percent of the total blood volume.

Hemibranch: One of the two series of filaments on a gill arch, "half gill".

Hermaphroditism: Having both sexes in the same individual.

Histology: The study of cellular and sub-cellular view of tissue, in other words the microscopic view.

Holobranch: Both of the paired series of filaments on a gill arch, "whole gill".

Holosteans: A taxonomic designation. An infraclass under the class osteichthyes (bony fishes), holosteans is the gars and bowfin.

Homeostasis: The maintenance of relatively stable conditions inside an organism despite a changing environment.

Hybridogensis: A condition where mating between a female and male of a related species produces a hybrid, but the male genes are lost during meiosis, so each generation is all female.

Hydrostatic pressure: The pressure (weight) exerted by a column of still water.

Hyperplasia: An increase in tissue mass caused by proliferation of cells resulting in more than the normal number of a given cell type.

Hypoxic: with low oxygen

in vitro: a Latin term meaning "in glass". In physiology, it refers to facts determined in a test tube outside of a living organism. The converse term is *in vivo*, "in life" referring to findings from living animals.

Kype: An extended jaw during spawning time, a male secondary sex characteristic of salmonid fish.

Lamellae (plural): The part of the gill similar to a capillary where blood/water exchange occurs, many lamellae branch off each filament. Sometimes termed "secondary lamellae". The singular is lamella.

Lamellar lacunae: The spaces inside the lamella in which blood can flow.

Lipase: An enzyme that breaks down fats and oils in the gut into smaller units for absorbtion.

Lumen: The inside of a hollow structure.

Myotomes: The bundles in which the white muscle of fish is arranged.

Neurons: nerve cells.

Neurotransmitters: Chemical compounds that act as local messengers to transmit nerve signals across synapses.

Obligate: Must follow a certain way of life, as opposed to facultative which may or may not follow that way of life, *e.g.* Tigers are obligated carnivores while humans are facultative carnivores.

Oral valve: Fish that have a respiratory pump have flaps behind each lip that act as a one way valve when the mouth is closed, preventing back flow of water out the mouth. Similarly, the opercula have a flap on the rear that seals the opercular opening during opercular expansion.

Osmosis: The movement of water through a semipermeable membrane. If the water on one side of the

membrane has more dissolved solids, the water will tend to move in that direction until the two sides are equally dilute.

Osmotic pressure: a measure of the tendency for water to move across a semipermeable membrane because of osmosis.

Otoliths: Literally "ear stones", small bits of bone found in the inner ear, some aid in hearing and others in gravity (which way is up?) Detection.

Oviparous: Egg-laying.

Ovoviparous: The egg is retained in the mother's body until hatching, but the female doesn't supply any nutrients to the embryo, only oxygen. The embryo develops on the energy in the yolk.

Parthenogenesis: A form of asexual reproduction where an all-female race requires sperm from a closely related species to trigger development of the egg, but no genetic material from the male is incorporated into the offspring.

Partial pressure: The physical pressure of oxygen on the surface of the water. It is termed "partial" because it is usually a fraction of the total gas pressure in a mixture of gases.

Pelagic: Open water dwelling.

Pheromone: a chemical substance that an animal makes to communicate outside the body, as opposed to a hormone that is used for internal communication.

Viviparous: live-bearing where, unlike ovoviparity, the female supplies nutrients to the developing embryos.

5.8 SELF ASSESSMENT QUESTIONS

1. Parasite chordate is_____

a) Exocoetus
b) Petromyzon
c) Amphioxus
d) No chordate s is parasites.

2 .Characteristic features of Cyclostomata_____

a) Round mouth
b) Round mouth with Jaws
c) Cylindrical mouth
d) Round mouth without Jaws & paired.

3. Jawless vertebrate are members of _____

a) Agnatha

b) Cephalochordata
c) Gnathostomata
d) Urochordata

4. Example of class cyclostomata are_____
a) Labeo & Catla
b) Mystus & Exocoetus.
c) Petromyzon & myxine
d) Scoliodon & Torpedo.

5. In cyclostomes, endoskeleton is _____
a) Cartilaginous
b) Bony
c) Both a & b
d) None of these

6. Poreson the body of a hagfish secretes:

(a) Sweat
(b) Mucus
(c) Slime
(d) Poison

7 Scale in Cyclostomata is:
(a) Placoid
(b) Absent
(c) Cycloid
(d) Ctenoid

8 Cranial nerve in cyclostometa is:
(a) 4-6 pair
(b) 6-8 pair
(c) 8- 10 pair
(d) 10- 12 pair

7 Members of the order Myxineforms are commonly known as:

(a) Lungfishes
(b) Sharks
(c) Lamprys
(d) Hagfishes

9. Passageof tube in the respiratory tube in Petromyzon is prevented:

(a) Oral hood

(b) Velum

(c) Sphincter muscles

(d) Scroll valve

10. The eggs of lampray are:

(a) Alecithal

(b) Mesolecithal

(c) Telolecithal

(d) Olegolecithal

Answers

1(b) 2(d) 3 (a) 4 (c) 5 (a) 6(c) 7 (a) 8 (c) 9 (d) 10 (b)

5.9 TERMINAL QUESTION ANSWERS

1. Distinguish between Agnatha & Gnathostomata?
2. Describe habit habitat and distribution of Petromyzon?
3. Draw a labeled diagram of Petromyzon?
4. Describe habit habitat and distribution of Myxin?
5. Draw a labeled diagram of Myxine?
6 .Give general characters and classification of Cyclostomata?
7. Give two example of jawless vertebrate?
8 .Give two examples of exoperasites on fishes?

5.10 REFERENCES

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UNIT: 6 FISH

CONTENTS

6.1 OBJECTIVE

- To understand the systematic and functional morphology of various groups of Fishes.
- To study their affinities and adaptations to different modes of life.
- To describe and explain the basic biology, evolution and development of fishes.
- To impart knowledge in comparative anatomy and development of fishes.

6.2 INTRODUCTION

A fish **(Fig: 6.1)** is any member of a paraphyletic group of organisms that consist of all gill-bearing aquatic craniate animals that lack limbs with digits. Included in this definition are the living hagfish, lampreys, and cartilaginous and bony fish, as well as various extinct related groups. Most fish are ectothermic ("cold-blooded"), allowing their body temperature to vary as ambient temperature changes though some of the large active swimmers like white shark and tuna can hold a higher core temperature. Fish are abundant in most bodies of water. They can be found in nearly all aquatic environments, from high mountain streams

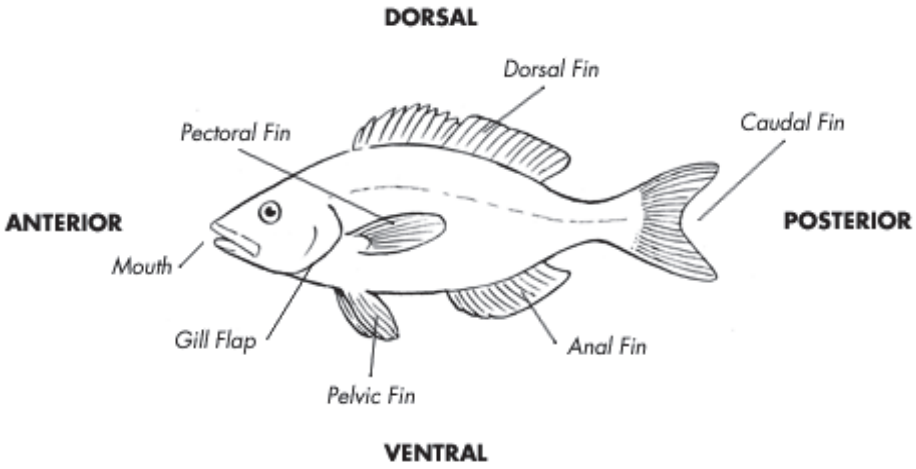


Fig 6.1 A Fish

(e.g., charand gudgeon) to the abyssal and even hadal depths of the deepest oceans (e.g., gulpers and angler fish). With 33,100 described species, fish exhibit greater species diversity than any other group of vertebrate.

Fishes are important resources for humans worldwide, especially as food. Commercial fishermen hunt fishes or farm them in ponds or in cages in the ocean. Fishes are also caught by recreational fishermen, kept as pets, raised by fishkeepers, and exhibited in public aquaria. Fish have had a role in culture through the ages, serving as deities, religious symbols, and as the subjects of art, books and movies.

Because the term "fish" excludes the tetrapods (i.e., the amphibians, reptiles, birds and mammals) which descend from within the same ancestry, it is paraphyletic, and is not considered a proper grouping in systematic biology.

6.3 GENERAL CHARACTERSTICS OF FISHES

a) Fishes are aquatic cold blooded vertebrates.
b) Their body is divisible into head, trunk and tail. Neck is absent.
c) It has a spindle shaped body. It is helpful in swimming.
d) The body is covered by scales. They are placoid scales, cycloid scales ,ctenoid scales, ganoid scales etc
e) Respiration is by gills. Gills are the extensions of the pharynx. In the elasmobranch fishes, the gill will open separate. In bony fishes the gill slits are covered by operculum.
f) On the head a pair of nostrils is present. Internal nostrils are visually absent. But Dipnoi i.e internal nostrils are present.
g) On the head a pair of eyes is present.
h) On the lateral sides of the body LATERAL LINE SENSE organs are present. They detect the pressure changes of water
i) The body shows paired and unpaired fins. Pelvic and pectoral fins are paired. Dorsal and ventral fins are unpaired. They maintain balance in water. They are useful for locomotion.

j) The digestive system is well developed. In the intestine of shark scroll valve Is present. The nervous system contains brain and spinal cord. Brain is small & it will not occupy the entire cranial cavity.

k) Ten pairs of cranial nerves are present.

l) Kidneys are mesonephrlc.

m) Urinary bladder is absent.

6.3.1 CLASSIFICATION OF FISHES

Fishes belong to Animal Kingdom are classified into Phylum Chordata and Subphylum Vertebrata. Fishes bear notochord, tubular nerve chord, paired gills, post anal tail, ventral heart and an endoskeleton. A vertebrate possess backbone, this back bone supports and protects the spinal cord.

The various species of fishes are classified into the following three groups:

- Agnatha - jawless fish
- Chrondrichthyes - cartilaginous fish
- Osteichthyes - bony fishes are devided into the following two groups.
  - Ray finned group
  - Lobe finned group

About 50 species of Agnatha, 600 species of Chrondrichthyes and 30,000 species of Osteichthyes are found in the world. Most of the fishes in the bony group belong to the ray finned group. According to the biologist about 70 fish orders are found in the world.

Sharks and rays; sturgeon and gars, herring-like fishes, trout and salmon, eels, minnows, suckers, and catfish; flying fish and relatives, cod-like fish, flatfish; seahorses and relatives; mullets, silversides, and barracuda, mackerels and tunas are the main groups of fishes.

Agnathan:-

Agnathan are jawless fish and lack paired fins. They also lack the internal skeleton system. They have a circular tooth mouth (cyclostomic) by which they bore the body of their victim and suck their blood. These are classified into two major groups as **Hagfishes** and **Lampreys**.

Characteristic of Agnatha

- Jaws are absent.
- Paired fins are absent.
- Bony scales and skin plates were present in the ancient species but are absent in the living species.
- Gill pouches are present. They have seven or more pouches.
- Stomach is absent in the digestive system.

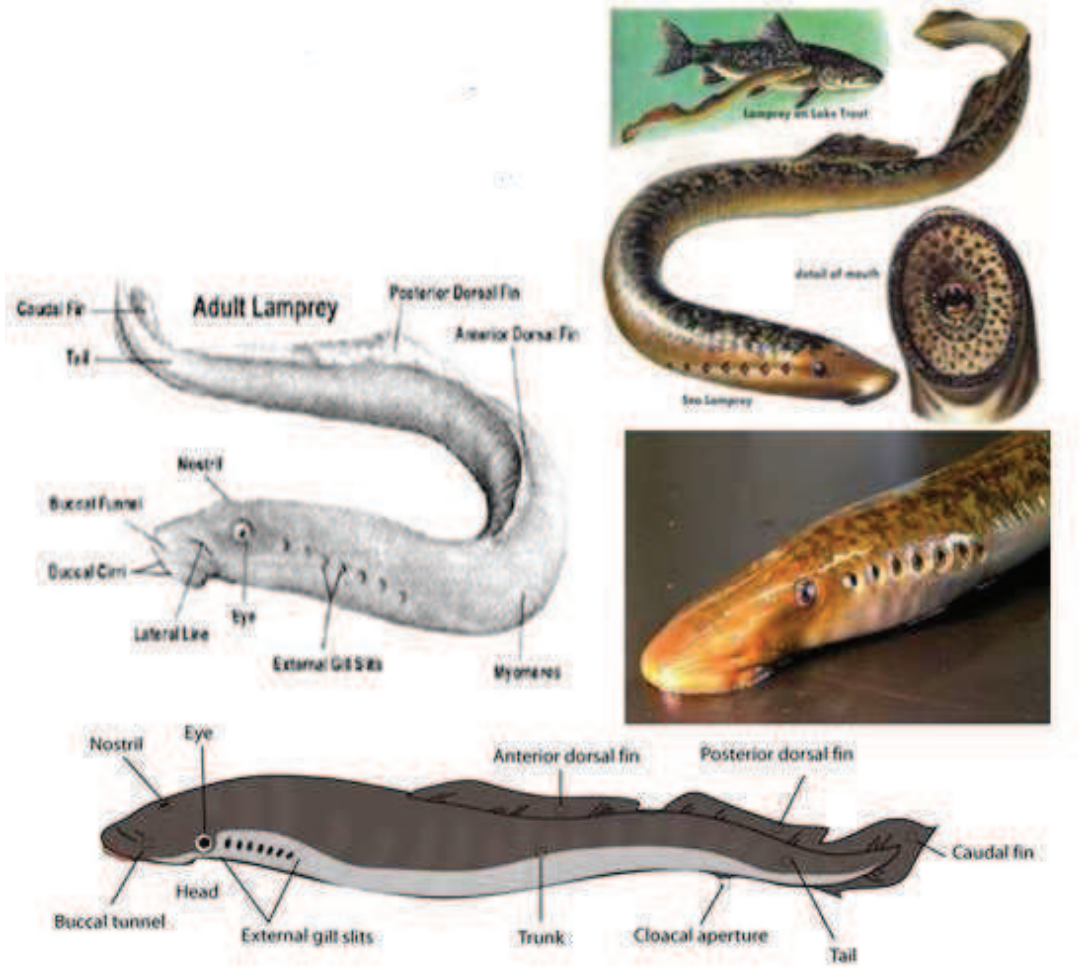


Fig.6.2 Class: Agnatha (Specimen: Lamprey)

Chrondrichthyes:-

Fearsome predators and harmless mollusc eaters are the members of the Chrondrichthyes. The cartilaginous fishes possess' true bone and also posses a skeleton made up of cartilage. Only the teeth of

this species and rarely the vertebrae are calcified. **Sharks**, **Skates**, and **Rays** make up the group of Chrondrichthyes.

Osteichthyes:-

About 30000 species of bony fish are found in this class. Fishes that belong to this group are spindle shaped, oval in section and flattened. Skins are protected by protective scales. Some fishes of this category have actual lungs to breathe and also have sharp eyesight. These bony fishes have a special gas filled chamber called air bladder housed under the skeleton to allow them to remain buoyant. Another adaptation is operculum, a bone on the sides of the fish to protect the chambers that house the gills.

Bony fish are again classified into ray finned and lobe finned fish. Ray finned fish have thin, flexible skeleton rays. Lobe finned fish have muscular fins supported by bones.

Characteristic of Osteichthyes:-

- They have more or less bony skeleton and numerous vertebrae.
- Mucous glands and embedded dermal scales are present in the skin.
- Have paired fins.
- Jaws are present.
- Gill arches support the gills and are protected by the operculum.
- Lungfish**,** Eels**,** Acrp**,** Lizardfish**,** Silversides and Salmon form the class of bony fishes.

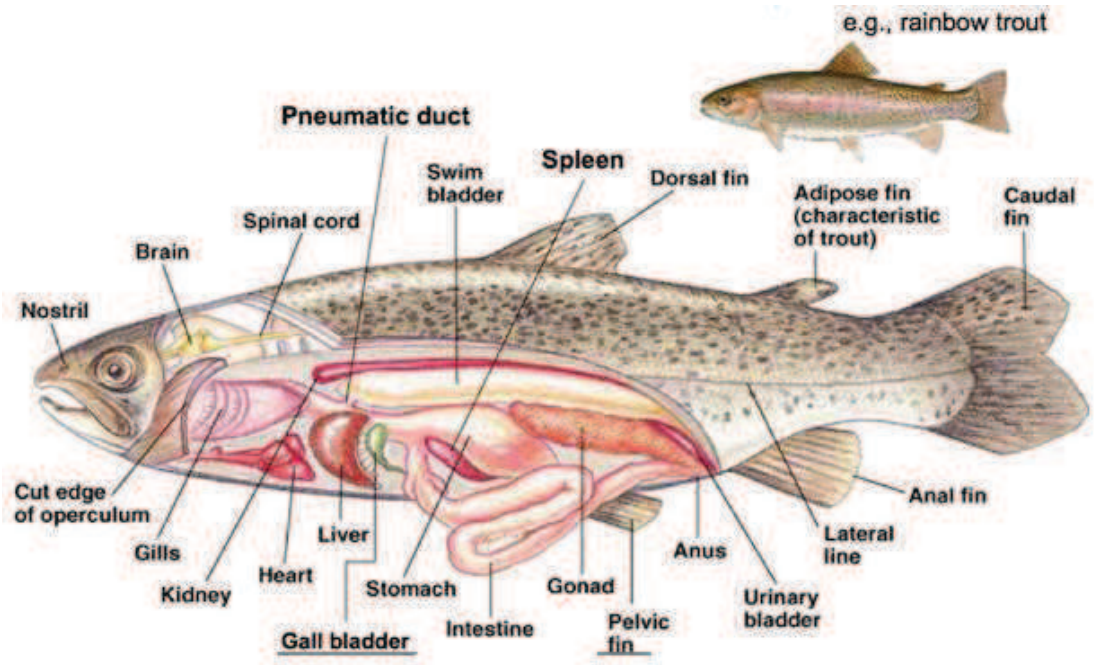


Fig.6.3 Internal organs of Phytostomous fish: Trout

6.4 *STUDY OF SCOLIODON*

Systematic position

Phylum	Chordate
Subphylum	Vertebrata
Division	Ganthostomata
Superclass	Pisces
Order	Squaliformes
Family	Carcharinidae
Genus	Scoliodon
Species	S.sorrakowah

Distribution:-

Genus Scoliodon is widely distributed in India, Pacific West India and eastern coasts of South America and Atlantic Oceans. The comman Indian dogfish is S sorrakowah which means “Black Shark, like most sharks, *Scoliodon* is marine, and is found in all open seas.

Habitat and Habitat:-

Body:

Scoliodon has an elongated, spindle-shaped, body tapered at the ends, making it a very fast swimmer. The trunk and tail are laterally compressed, while the head region is dorsoventrally compressed. The entire body is covered by an exoskeleton of placoid scales. The mouth is located on the ventral side and is bound on both sides by jaws. It has two rows of homodont orpolyphyodont teeth, which are homologous to the placoid scales covering the body.

Morphology:

Full-grown specimen measures from 40-60 cm in length. The body is divisible into head, trunk and tail. The head is dorsoventrally compressed and anteriorly terminates a flat snout. The trunk attains maximum thickness in the middle region and gradually tapers posteriorly into a long tail.

The tail bears heterocercal type of caudal fin. Heterocercal means ventral hypochordal lobe is well developed than the dorsal epichrodal lobe. There are shallow pits called caudal pits at the root of the tail both on dorsal and ventral sides. These are characteristics of scoliodon. The mouth is wide crescentic aperture on the ventral side of the head. It is bounded by upper and lower jaws. Each jaw is armed teeth to catch the slippery pray. The teeth of the scoliodon are modified scales. The placoid scales cover its body and extend inside the jaw to serve as teeth.

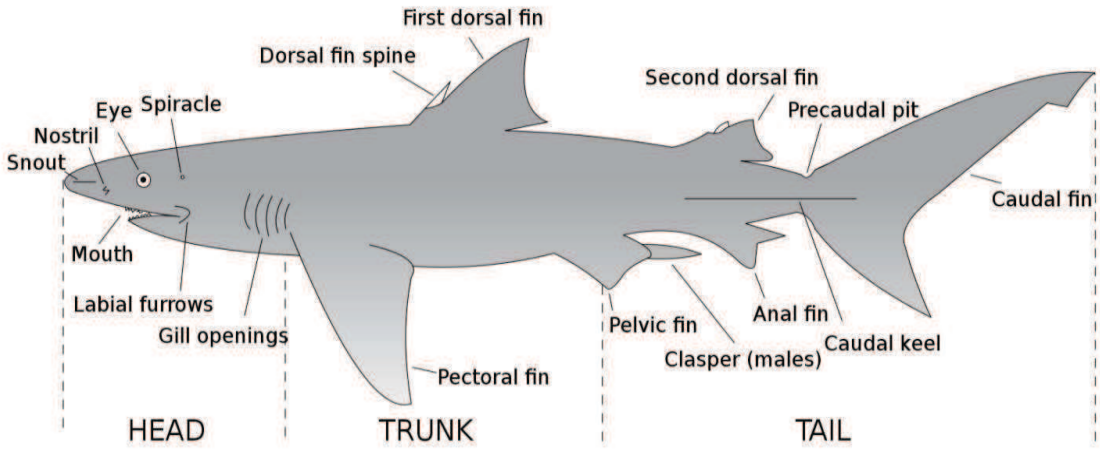


Fig.6.4 Scoliodon

On each side of head is a large circular eye. Each eye is provided with movable upper and lower eyelids. The third eye lid or nictitating membrane can cover the whole eye during emergency. The pupil is a vertical slit like aperture. Two nostrils are present at the anterior part of the snout. They lead into olfactory sacs. These are exclusively olfactory in function and they have no connection with mouth cavity. Each nostril is partly covered by a small fold of skin. Posterior to eye on either side of the head are situated five vertical slits called gills lits or branchial slits. These slits lead into gill pouches and then into pharynx. Operculum or gill cover is absent.

Many pores called ampullary pores are also present on the head. These are pores of the sense organ, ampulla of Lorenzini. The cloaca opens to the anterior by a cloacal aperture, which lies between two pelvic fins. The cloacal aperture is an elongated opening. The cloacal is common chamber into which receives faecal matter, urine and gametes. On each side of the cloaea lie abdominal pores.

Fins:

The fins are thin, flat out growths of skin with muscles and are supported by cartilaginous rods or rays. Scoliodon is provided with unpaired median fins i.e. 1st dorsal fin, second dorsal fin, second dorsal fin, caudal fin, anal fin and paired fins (anterior pair pectoral fins and posterior lateral pelvic fins). The pectoral fins are large and are situated posterior to the gill clefts. The pelvic fins are simple but in males, the inner margin of the pelvic fins bear a pair of rod shaped copulatory organs called clasper or myxipterygium. The claspers are the intermittent organs that introduce sperm into female genital tract. The fins propel the body in forward direction during swimming.

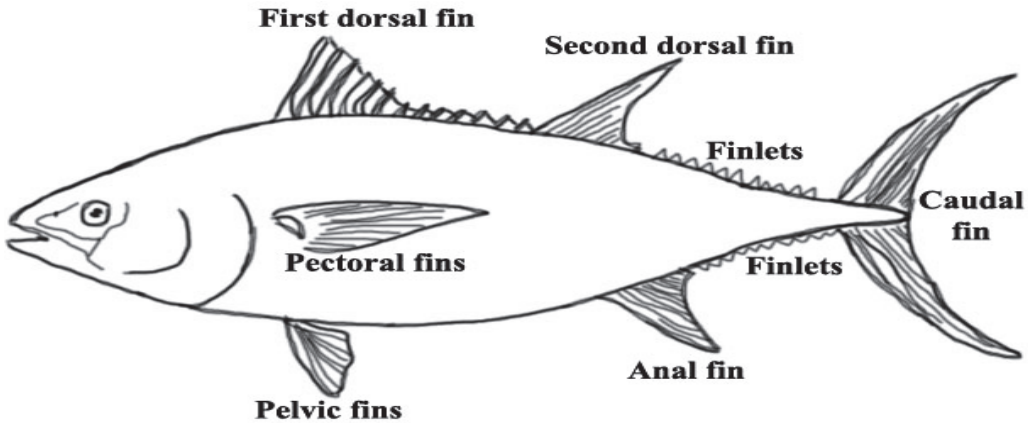


Fig.6.4 Different type of fins

Mouth:

It is situated a little behind the apex on the ventral side of the anterior region of the body. Mouth is bounded by upper and lower jaws each bearing 1 or 2 rows of sharply, pointed and backwardly directed teeth. Teeth are adapted for holding and tearing of the prey.

Nares:

Two crescentic apertures, the nares or nostrils are present ventro-laterally and anterior to mouth. They are exclusively olfactory, have no role in respiration, as they are not connected to mouth cavity by internal nostrils.

External gill slits:

Anterior to each pectoral fin, on either side of the body vertically elongated external gill slits or branchial clefts are present in a series of 1 to 5. They are main respiratory organs.

Cloacal aperture:

Between two pelvic fins, on the tail region an elongated median groove or cloacal aperture is found, it leads to a small chamber, the cloaca, which is the common exit for digestive and urinogenital and urinogenital system.

Abdominal pores:

Within either lateral edge of cloaca, the abdominal pores are situated on elevated papillae. The abdominal cavity opens to the exterior through abdominal pores.

Caudal pits

At the base of caudal fin the tail bears two shallow depressions, one dorsal and one ventral, known as caudal pits, which are characteristics of the genus scoliodon.

Lateral line and pores:

A faint lateral line runs along either lateral side of the body. It marks the position of an underlying sensory lateral line canal system which opens outside at intervals through minute pores.

Ampullary pores: -

On the head and snout several minute ampullary pores of the ampullae of lorenzini open at dorsal surface. They secrete mucus when pressed.

Digestive system:

Digestive system consists of alimentary canal and associated glands.

Alimentary canal:

It is complete and is divided into buccal cavity, pharynx, oesophagus, stomach, intestine and rectum. The stomodeal portion is lined with ectoderm. The mesodaeum is lined with endoderm. The proctodaeum is also lined with ectoderm.

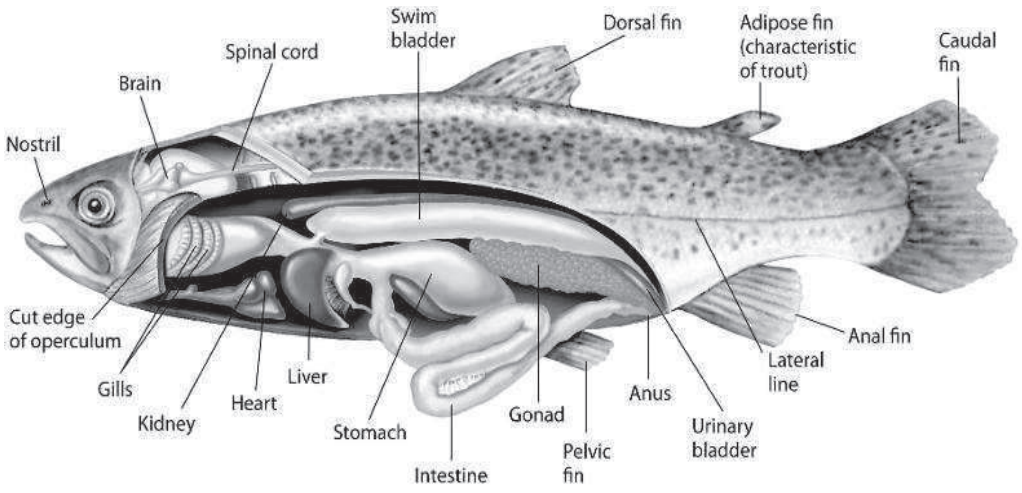


Fig.6.5 Internal organs of Phytostomous fish: Trout

Mouth: -It is a semioval slit bounded by upper and lower lips and is present at the ventral side.

Buccal Cavity:

It is a wide cavity containing sharp pointed backwardly directed homodont and polyphyodent type of teeth. These are mainly used merely to prevent the escape of prey.The mucous membrane is raised to form the tongue which is glandular and muscular.

Pharynx:

It is a large wide chamber which opens through five vertical slits called internal gillslits which open into gills. The mucous membrane contains numerous denticles to prevent the escape of prey.

Oesophagus:

The pharynx opens into a short narrow thick, muscular oesophagus containing rugae. It remains closed, except during swallowing of food, to check the entry of water into stomach. It opens into stomach, through oesophageal valve.

Stomach:

It is 'J' shaped bent tube which is divided into two parts.

Cardiac Stomach:

It is a long, broad muscular part containing longitudinal folds. At the end there is a cardiac valve.

Blind Sac:

At the end of cardiacs stomach starts there us a small, outgrowth called blindsac of unknown function.

Intestine:

It is a straight wide tube which is divided into duodenum and ileum.

Duodenum:

It is the narrow, anterior part. It receives common bile duct or ductus choledochus dorsally and pancreatic duct ventrally.

Ileum:

The rest part of intestine is called as ileum. The mucous membrane is produced into scroll valve. One edge if the is valve is attached to the intestinal mucosa.But the other end roles up spirally in anticlockwise manner upto two and halfturn. The scroll valve increases the inner absorptive area. The passage of foodslows down in scroll valve to ensure proper absorption.The intestine is not connected with mesentery and is opened into the rectum.It is a short narrow straight tube suspended by mesorectum. In between ileum and rectum there is rectal valve containing circular muscles. It receives rectal gland which is similar to medulla of kidney and excretes excess salts. Rectum leads to cloaca.

Cloaca:

It is a short terminal chamber, which receives ducts of urinogenital system. It has a pair of abdominal pores.

Cloacal aperture:

It is a small longitudinal aperture present between two pelvic fins.

Digestive glands:

Liver is a large yellowish two lobed gland present in between stomach and is suspended by falciform ligaments, gastrohepatic omentum and hepatoduodenal ligament. The V-shaped gall-bladder stores bile and drains by cystic duct which fuses with hepatic duct to form common bile duct. It opens into deudenum.

Pancreas:

It is an elongated, whitish gland present between two limbs of the stomach. It is divided into two lobes. The dorsal lobe is present parallel to the posterior part of the cardiac stomach- and ventral lobe, closed to the pyloric stomach. The pancreatic duct opens into the ventral wall of the duodenum.

Absorption:

The spiral valve extends to the area of absorption and slows down the passage of food or

Respiratory System

In Scoliodon **respiration** takes place through 5 pairs of gill slits or gill pouches. They are present in a series on the wall of pharynx on either lateral side, behind the hyoid arch. Each gill pouch opens into the pharynx by a large branchial aperture and to outside through an external branchial aperature or gill slit. Two adjacent gill pouchesare completely separated by a vertical fibro-muscular partition, the interbranchial or gills septum.

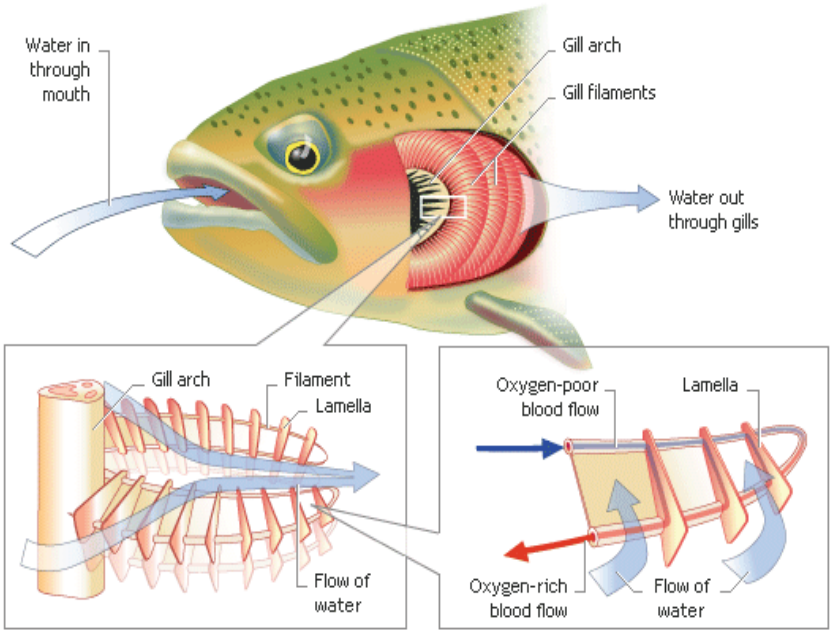


Fig.6.6 Respiratory system

The inner or pharyngeal border of each gill septum is supported by a cartilaginous visceral arch or gill arch with its slender branchial rays. The septum is covered by epithelium and contains b lood vessels, nerves etc.The mucus membrane of a septum is raised into numerous horizontal leaf like folds called gill

lamellae or gill filaments.These constitute the gill proper and are richly supplied with blood capillaries. Each septum bears two sets of gill-lamellae, one on its anterior face and the other on its posterior face. Each set makes a half gill called demibranch.

A gill pouch thus contains two demibranchs belonging to two different adjacent gills. In Scoliodon, the hyoid arch bears only a demibranch on its posterior face.The first four branchial arches bear holobranchs while the fifth one is devoid of gills and is called abranch.In front of hyoid arch or the first internal gill slit is an oval pit of spiracle. It has no gill lameliae or external opening and is regarded as vestigeal gill pouch.However, in some other elasmabranchs it bears minute gill lamellae and opening, which is called pseudobranch.

6.5 DIFFERENT TYPES OF SCALES IN FISHES

Placoid scales

Placoid scales are found in thecartilaginous fishes: sharks, rays, and chimaeras. They are also called *dermal denticles*. Placoid scales are structurally homologous to the vertebrate teeth ("denticle" translates to "small tooth"), having a central pulp cavity supplied with blood vessels, surrounded by a conical layer of dentine, all of which sits on top of a rectangular basal plate that rests on thedermis. The outermost layer is composed of vitrodentine, a largely inorganic enamel-like substance. Placoid scales cannot grow in size, but rather more scales are added as the fish increases in size. Similar scales can also be found under the head of the denticle herring. The amount of scale coverage is much less in rays and chimaeras.

The skin of sharks is entirely covered by placoid scales. The scales are supported by spines, which feel rough when stroked in a backward direction but, when flattened by the forward movement of water, create tiny vortices that reduce hydrodynamic drag, making swimming both more efficient as well as quieter compared to that of bony fishes. The rough, sandpaper-like texture of shark and ray skin, coupled with its toughness, has led it to be valued as a source of rawhide leather, called shagreen. One of the many historical applications of shark shagreen was in making hand-grips for swords.

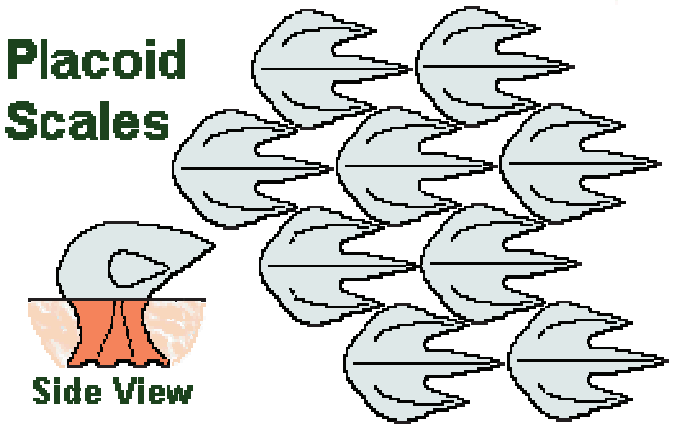


Fig.6.7 Placoid scale

Unlike bony fish, sharks have a complicated dermal corset made of flexible collagenous fibers arranged as a helical network surrounding their body. The corset works as an outer skeleton, providing attachment for their swimming muscles and thus saving energy. Their dermal teeth give them hydrodynamic advantages, as the scales reduce the turbulence of swimming.

Cycloid scales

Cycloid (circular) scales have a smooth texture and are uniform, with a smooth outer edge or margin. They are most common on fish with soft fin rays, such as salmon and carp.

Ctenoid scales

Ctenoid (toothed) scales are like cycloid scales, with small teeth along their outer edges. They are usually found on fishes with spiny fin rays, such as the perch-like fishes. The scales have a rough texture with a toothed outer or posterior edge featuring tiny teeth called **ctenii**. These scales contain almost no bone, being composed of a surface layer containing hydroxyapatite and calcium carbonateand a deeper layer composed mostly of collagen. The enamel of the other scale types is reduced to superficial ridges and ctenii.

Ctenoid scales can be further subdivided into three types:

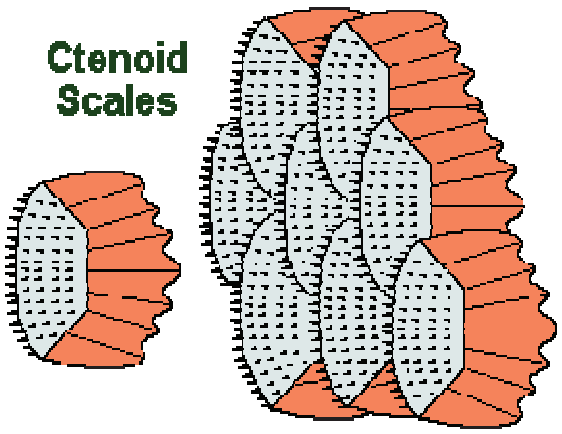


Fig.6.8 Ctenoid Scale

- **Crenate** scales, where the margin of the scale bears indentations and projections.
- **Spinoid** scales, where the scale bears spines that are continuous with the scale itself.
- **True ctenoid** scales, where the spines on the scale are distinct structures.

Both cycloid and ctenoid scales are overlapping, making them more flexible than cosmoid and ganoid scales. Unlike ganoid scales, they grow in size through additions to the margin. The scales of some species exhibit bands of uneven seasonal growth called **annuli** (singular **annulus**). These bands can be used to age the fish. Most ray-finned fishes have ctenoid scales. Some species of flatfishes have ctenoid scales on the eyed side and cycloid scales on the blind side, while other species have ctenoid scales in males and cycloid scales in females.

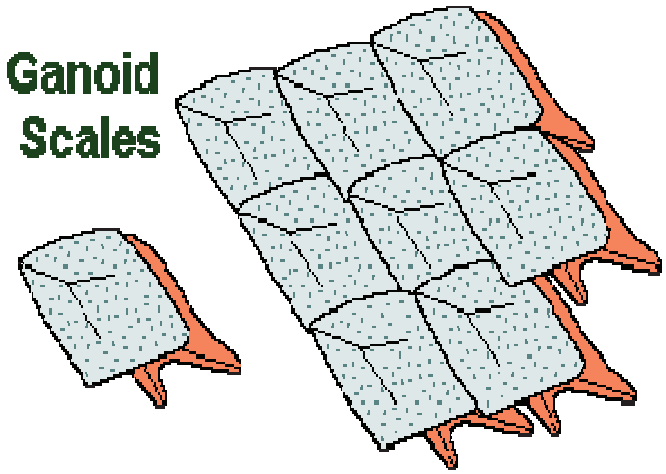


Fig.6.9 Ganoid Scale

Ganoid scales are found in the sturgeons, paddlefishes, gars, bowfin, and bichirs. They are derived from cosmoid scales, with a layer of dentine in the place of cosmine, and a layer of inorganic bone salt called ganoine in place of vitrodentine. Most are diamond-shaped and connected by peg-and-socket joints. They are usually thick and do not overlap. In sturgeons, the scales are greatly enlarged into armour plates along the sides and back, while in the bowfin the scales are greatly reduced in thickness to resemble cycloid scales (see above).

Cosmoid scales

Cosmoid scales were found in several ancient lobe-finned fishes, including some of the earliest lungfishes, and were probably derived from a fusion of placoid scales. They are composed of a layer of dense, lamellar bone called isopedine, above which was a layer of spongy bone supplied with blood vessels.

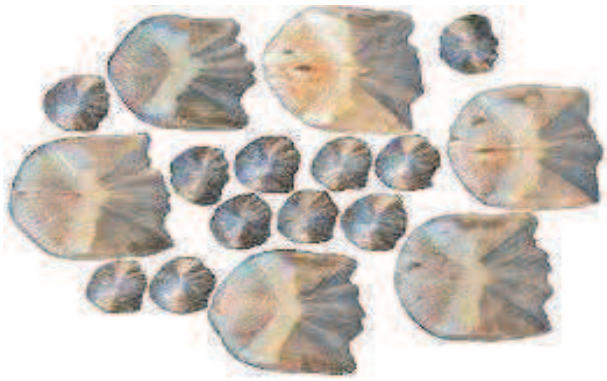


Fig.6.10 Cosmoid Scale

The bone layers are covered by a complex dentine layer called cosmine and a superficial outer coating of vitrodentine. Cosmoid scales increase in size through the growth of the lamellar bone layer.

6.6 DIFFERENT TYPES OF FINS IN FISHES

Pectoral fins

The paired pectoral fins are located on each side, usually just behind the operculum, and are homologous to the forelimbs of tetrapods.A peculiar function of pectoral fins, highly developed in some fish, is the creation of the dynamic lifting force that assists some fish, such as sharks, in maintaining depth and also enables the "flight" for flying fish.

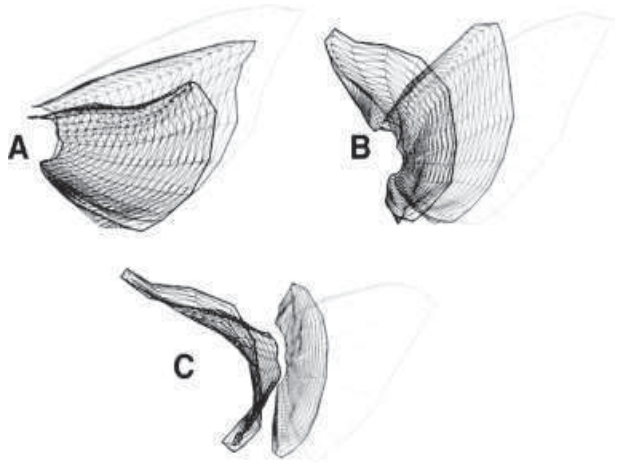


Fig 6.11Pectoral Fins

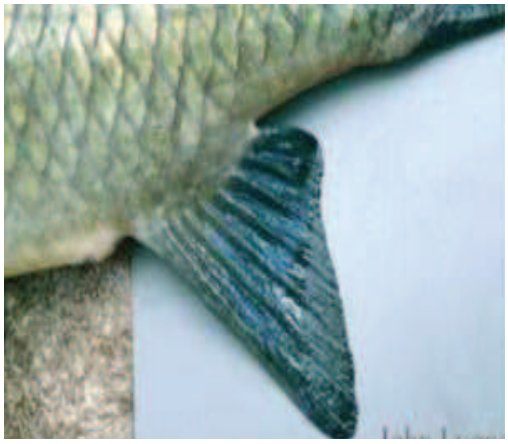
In many fish, the pectoral fins aid in walking, especially in the lobe-like fins of some anglerfish and in the mudskipper.

Certain rays of the pectoral fins may be adapted into finger-like projections, such as in sea robins and flying gurnards.

The "horns" of manta rays and their relatives are called cephalic fins; this is actually a modification of the anterior portion of the pectoral fin.

Anal (Tail fin) Fin:

The **anal fin** is located on the ventral surface behind the anus. This fin is used to stabilize the fish while swimming.



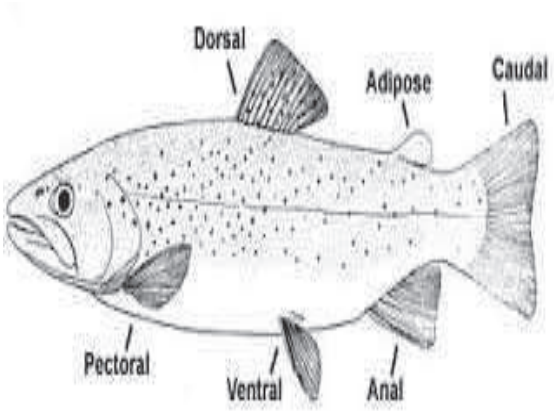


Fig.6.12 Adipose fin of Trout

The **adipose fin** is a soft, fleshy fin found on the back behind the dorsal fin and just forward of the caudal fin. It is absent in many fish families, but is found in Salmonidae, characins and catfishes. Its function has remained a mystery, and is frequently clipped off to mark hatchery-raised fish, though data from 2005 showed that trout with their adipose fin removed have an 8% higher tailbeat frequency. Additional information released in 2011 has suggested that the fin may be vital for the detection of, and response to, stimuli such as touch, sound and changes in pressure. Canadian researchers identified a neural network in the fin, indicating that it likely has a sensory function.

Caudal Fin (Tail Fin):-

The **caudal fin** is the tail fin (from the Latin *cauda* meaning tail), located at the end of the caudal peduncle and is used for propelsion. *See body-caudal fin locomotion.*

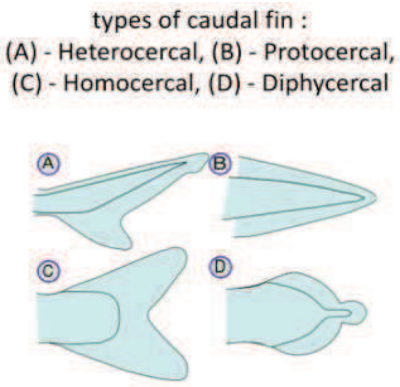


Fig.6.13 Caudal Fin

(A) - **Heterocercal** means the vertebrae extend into the upper lobe of the tail, making it longer (as in sharks).

- **Reversed heterocercal** means that the vertebrae extend into the lower lobe of the tail, making it longer (as in the Anaspida).

(B) - **Protocercal** means the vertebrae extend to the tip of the tail and the tail is symmetrical but not expanded (as in amphioxus).

(C) - **Homocercal** where the fin appears superficially symmetric but in fact the vertebrae extend for a very short distance into the upper lobe of the fin.

(D) - **Diphycercal** means the vertebrae extend to the tip of the tail and the tail is symmetrical and expanded (as in the bichir, lungfish, lamprey andcoelacanth). Most Palaeozoic fishes had a diphycercal heterocercal tail.

6.7 MIGRATION IN FISHES

Many types of **fish migrate** on a regular basis, on time scales ranging from daily to annually or longer, and over distances ranging from a few metres to thousands of kilometres. Fish usually migrate to feed or to reproduce, but in other cases the reasons are unclear.

Migration involves the fish moving from one part of a water body to another on a regular basis. Some particular types of migration are anadromous, in which adult fish live in the sea and migrate into fresh

water to spawn, and catadromous, in which adult fish live in fresh water and migrate into salt water to spawn.

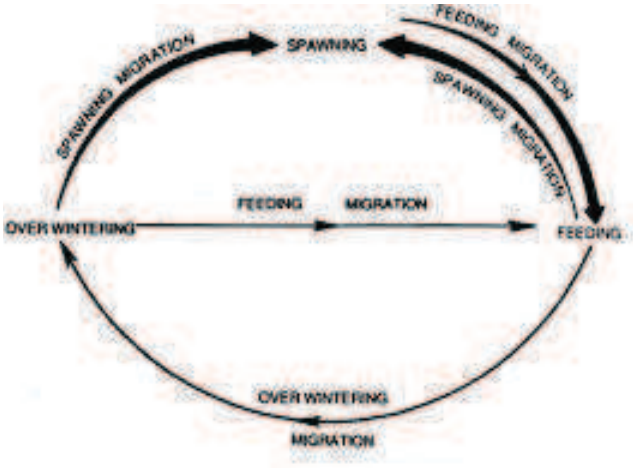


Fig.6.14 Migration cycle of various fishes

Marine forage fish often make large migrations between their spawning, feeding and nursery grounds. Movements are associated with ocean currents and with the availability of food in different areas at different times of year. The migratory movements may partly be linked to the fact that the fish cannot identify their own offspring and moving in this way prevents cannibalism. Some species have been described by the United Nations Convention on the Law of the Sea as highly migratory species. These are large pelagic fish that move in and out of the exclusive economic zones of different nations, and these are covered differently in the treaty from other fish.

Salmon and striped bass are well-known anadromous fish, and freshwater eels are catadromous fish that make large migrations. The bull shark is aneuryhaline species that moves at will from fresh to salt water, and many marine fish make a diel vertical migration, rising to the surface to feed at night and sinking to lower layers of the ocean by day. Some fish such as tuna move to the north and south at different times of year following temperature gradients. The patterns of migration are of great interest to the fishing industry. Movements of fish in fresh water also occur; often the fish swim upriver to spawn, and these traditional movements are increasingly being disrupted by the building of dams.

Classification

As with various other aspects of fish life, zoologists have developed empirical classifications for fish migrations. Two terms in particular have been in long-standing wide usage:

Anadromous fishes migrate from the sea up into fresh water to spawn, examples - salmon, striped bass.

Catadromous fishes migrate from fresh water down into the sea to spawn.

6.8 PARENTAL CARE IN FISHES

Parental care, the investment in young after fertilization, may not be a behavior that immediately jumps to your mind when you think of fishes. However, many fishes provide care for their young, and they care for the young in different ways. Which parent provides the care also varies greatly from fish species to fish species.The impressive variation in parental-care tactics has made fishes an excellent group for testing our understanding of how parental care evolves.

Indeed, studies with bony fishes have helped shape our theoretical understanding of how sexual selection operates. In contrast, the physiological mechanisms underlying parental behavior in fishes remain poorly explored.

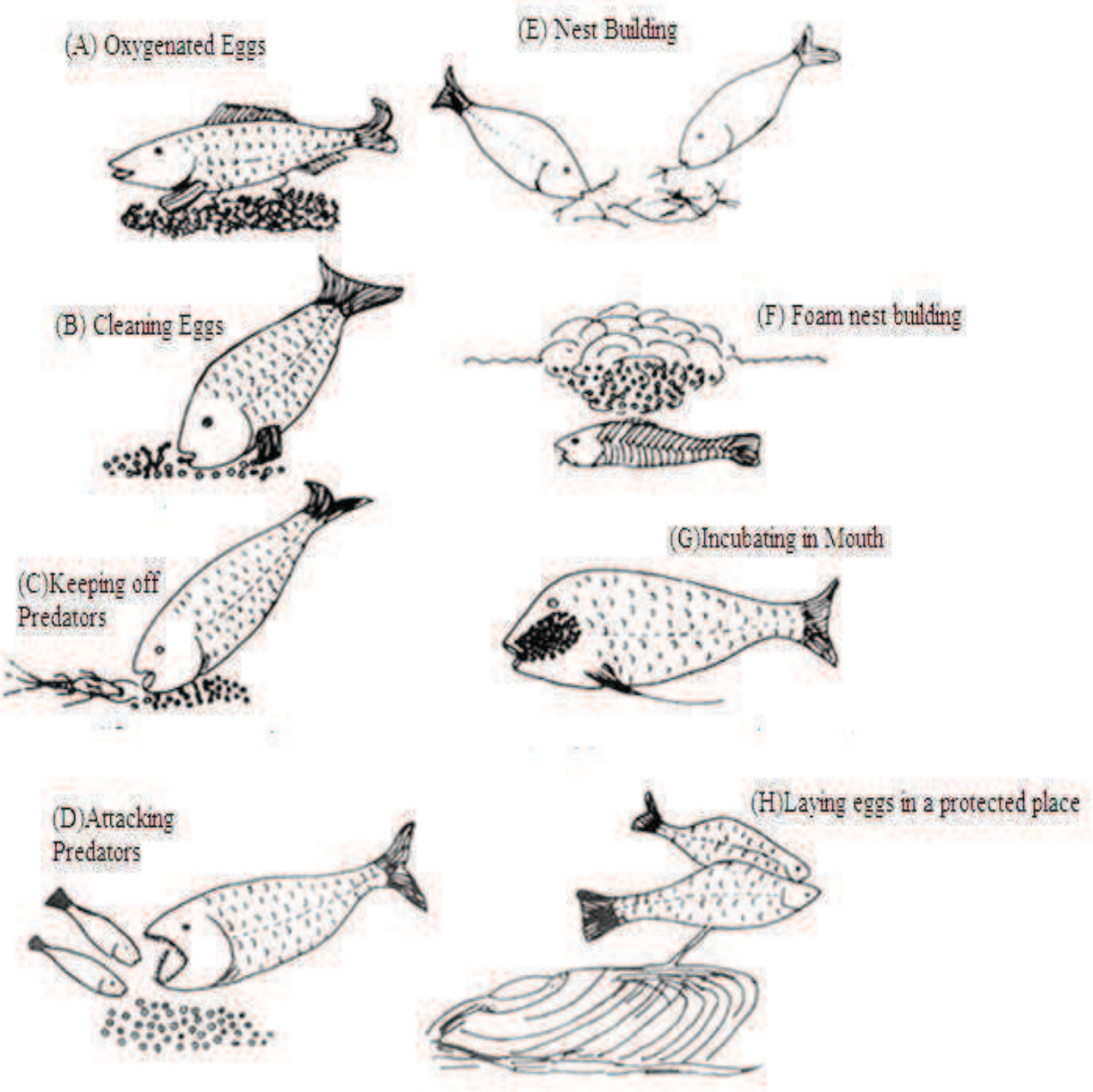
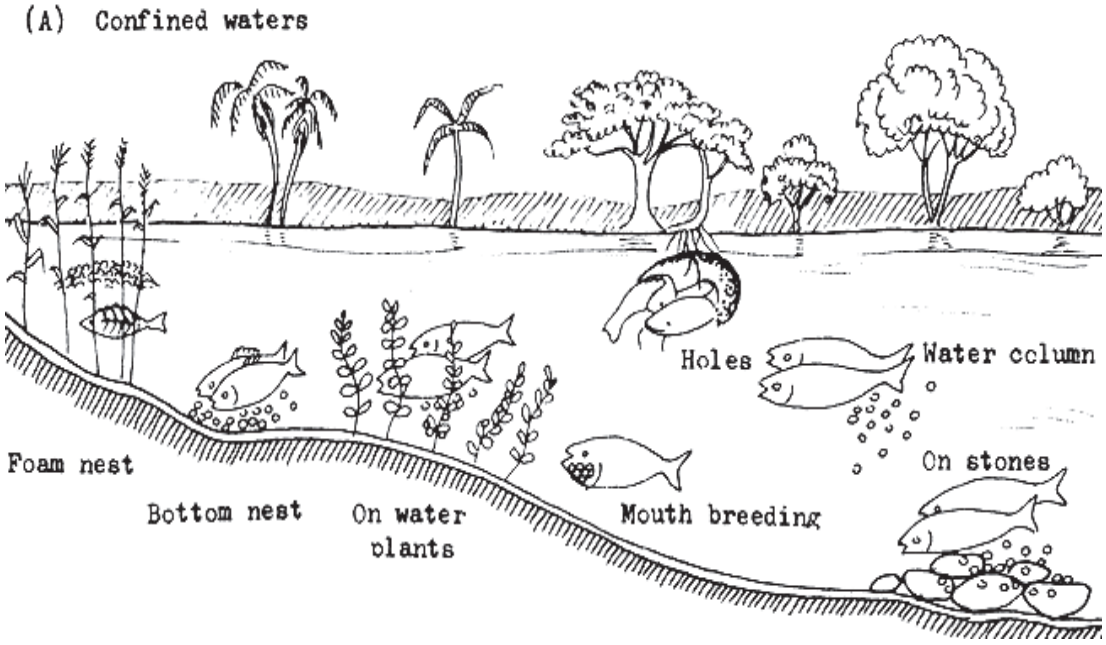


Fig.6.15 Parental care in fishes

Although to a limited degree prolactin, isotocin, and androgens have all been investigated in the context of parental care, the behavioral physiology of parental care in fishes is very much in its infancy. In this article, we examine the major forms of care and the common patterns of care found in fishes. We then provide an explanation for these patterns based on the costs and benefits of parental care. Finally, we review the current available information on physiological underpinnings of fish parental- care behavior,

albeit limited, and suggest areas for much-needed future research. Before embarking on a review of parental care in fishes, it is necessary to clarify the terms used when describing behavior of parents toward their young. The term ‘parental care’ is used to describe any behavior performed by parents that appears likely to improve the survival and reproduction of the young.

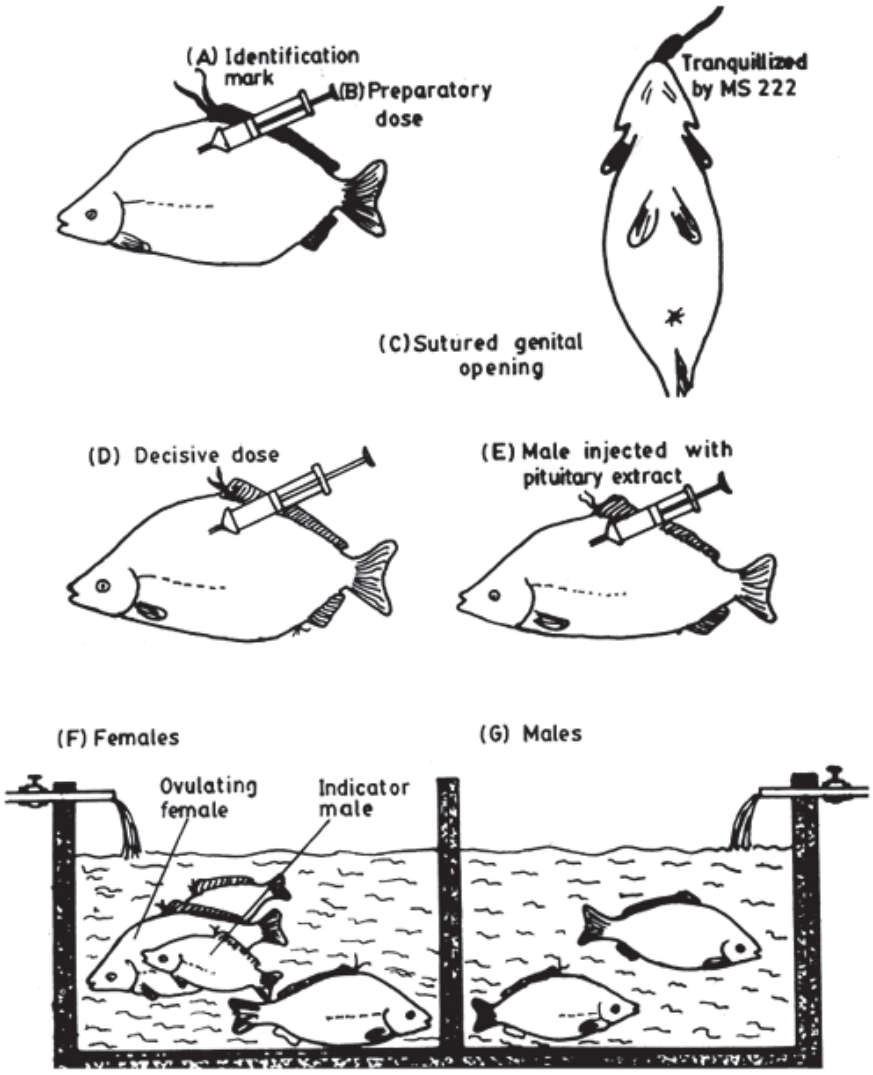
Robert Trivers coined a more restrictive term ‘parental investment’ to refer to any action by parents that increases offspring fitness at a cost to parental fitness (because it curtails their ability to invest in future mating, fecundity, survival, or further parental care). The terms parental effort or parental expenditure refer specifically to the time and effort spent on parental care of offspring, again referring to actions that are thought to increase offspring fitness, for example, defending offspring against predators. This measure is related to parental investment but does not necessarily imply fitness costs for parents, as the costs of parental care may change with an individual’s age, status, or condition.



The

question of which behaviors to include or exclude when using the terms parental care or parental investment can also be challenging. For example, building and defending a nest may not only increase the chances of attracting a mate (reproductive effort), but also have a positive impact on offspring fitness (parental effort). Many fish species provide eggs with large quantities of yolk before releasing them to the external environment.

Behaviors: Nutritional Provision During Parental Care); the largest known fish egg belongs to the coelacanth (*Latimeria chalumnae*) with a diameter between 7.5 and 9.0 cm and a mass of 325 g. Whether or not such provisioning should be considered as parental care or parental investment has been much debated. Females vary considerably (within and across species) in the extent to which they provision eggs and such provisioning has profound effects on development time, survival of young, and the ability for a female to invest in future young.

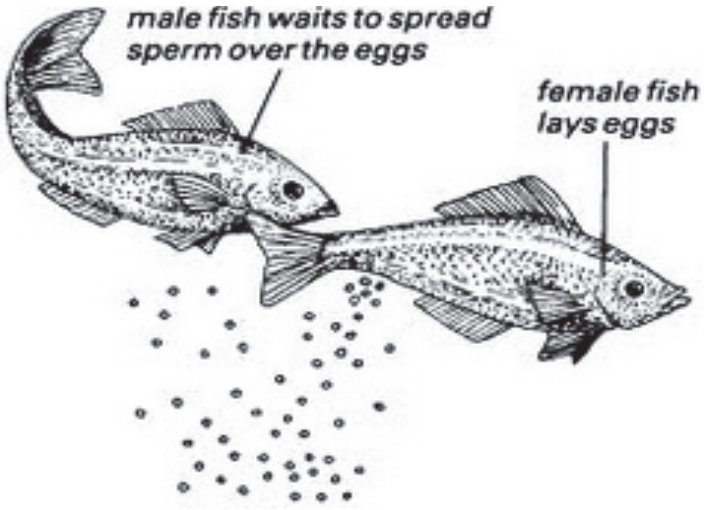


Patterns and Diversity in Parental Care

Form of Care Unlike birds and mammals where offspring require some form of parental assistance, most fish species do not provide parental care. However, in 25% of fish species, care has evolved, and the way care is performed is highly variable Fish care ranges from hiding of eggs and then abandoning the area, to guarding young in elaborately prepared structures for up to several months, and from carrying young in or on the parent's body cavity to the feeding of young. The simplest form of fish parental care is hiding of the eggs. Female salmon and trout, for example, will excavate nests (redds) by digging simple depressions with their tails; the eggs that are laid in these redds are fertilized and then buried by the female. In contrast to the simple pit built by the female salmonids, some fish species are amazing construction workers. Lake Malawi's cichlid, *Cytocaraeucinostomus,* creates crater-shaped nests that are more than 3 m in diameter, while the three-spined stickleback, *Gasterosteus aculeatus*, constructs elaborate nests woven of plant

material carefully glued together with a special kidney glycoprotein secretion known as spiggin Social and Reproductive Behaviors: Sexual Behavior in Fish).

Although the terms 'brooding' and 'incubation' are commonly used by fish biologists when describing fish parental care, fish do not truly incubate eggs, as heat is not transferred to the eggs by parents. However, many fish species protect their young internally and some even have live births (known as live-bearing or viviparous species. Nutritional Provision During Parental Care). Species of fish that protect or incubate their young internally may do so in their mouths (e.g., marine catfishes and cichlids, in ventral brood pouches (e.g., sea horses and pipefishes, on hooks (e.g., *Kurtus* spp.), embedded in skin (e.g., American banjo catfish, or in gill chambers (e.g., cavefish). Internal brooding is an extremely effective method of protection because the only way a predator can capture or kill young fish is to injure or kill the parent or force the parent to eject its young. For example, male seahorses, *Hippocampus wheitei*, receive eggs from their female partners, which the males internally fertilize and then aerate and nourish for a few weeks in an enclosed pouch.

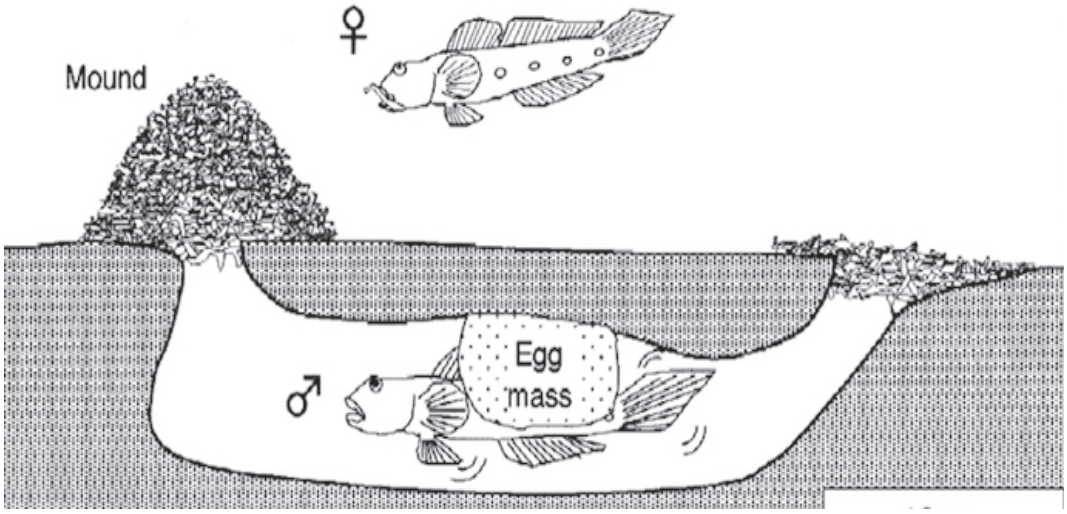


The dads eventually give birth (via a series of forward and backward muscular contortions) to young, one at a time. The most complex or elaborate parental-care behaviors found in fishes are undoubtedly the feeding of young post-hatch and caring for nutritionally independent young. *Symphysodon discus* young as well as the young of some other cichlid species ingests the epidermal mucus from their parents' body. Both male and female parents of the Central American convict cichlid, *Cichlasoma nigrofasciatum*, carefully lift up fallen leaves for their young providing them with benthic prey underneath the leaf litter. Many cichlid parents appear to be able to signal imminent danger to their

young by using a specific jolt or calling behavior that consists of open-and-shut snapping of the pelvic fins while swimming backward with the head pitched downward. The young respond to these warning movements by settling down into the substrate or swarming and entering the parents' mouths where they can be kept safely until the danger has passed. Finally, in Tanganyikan cichlids, such as *Neolamprologus brichardi and Neolamprologus pulcher*, sexually mature young continue to be vigorously guarded.

Explaining the Patterns and Diversityof Fish Parental Care

Many interesting questions arise from the patterns observed in fish parental behavior. For example, (1) why do so many more freshwater fishes provide care (57% of freshwater fish families) compared to marine species (only 16%); (2) why is female-only (maternal) care typically associated with internal bearing in fishes; and (3) why is male-only (paternal) care so common? This section addresses these related questions about who should care, and it reviews the costs and benefits associated with parental care in fishes:

1. 

Why so much care in freshwater species?

The open Ocean provides a relatively stable, safe, and homogeneous environment for egg development; egg predators are relatively rare and water conditions do not fluctuate quickly. In contrast, freshwater biotas, especially shallow ones where fish eggs are typically released, vary tremendously in time and space. Hence, selection of particular spawning locations combined with parental care can have massive impacts on egg development and survival. This benefit has led to male defense of the best or favored female spawning sites and to female egg clumping. Under these conditions (male territoriality and

multiple females being attracted to the same spawning site), guarding eggs in addition to a territory would not be particularly costly.

2. *Why is female-only or maternal care associated with internal*
Bearing in fishes? Internal gestation is rare in fishes (11% of families) and is strongly associated with female care. Once internal fertilization has evolved, the retention of egg requires little re-organization and would confer a substantial survival benefit to young. A protracted association between females and the zygote is considered to be the basis for selection of internal fertilization. In families with internal fertilization and care, in 86% of the cases it is the female that provides the care; in contrast, when external fertilization and parental care co-occur, it is usually the male that provides care (76% of cases).

3. Why so much male-only (paternal) care in fishes?

A lot of theory has centered on why, in contrast to other animals, in fish, it is the males that usually provide care. Initially, it was thought that higher rates of paternity, associated with external fertilization in fishes predisposed males to care. However, external fertilization does not protect against paternity loss; sneaker tactics and strong sperm competition have evolved many times in fishes and paternity certainly does not cause male care. Later, it was argued that the order in which gametes are released predisposes male fish to care, because in external fertilizing fishes, females shed eggs before males shed sperm, effectively providing females with an opportunity to desert their partners. Hence, male externally fertilizing fish are abandoned in the cruel bind of being left in charge the lowest costs of care will provide care and that theseof the babies. However, for the majority of externally costs of care are lower for the sex already associated with fertilizing fishes, both males and females release gametes the young. This is the female for internal fertilizing fishes, simultaneously. In some species (e.g., black gobies), caring while it is the male for external fertilizing species with male males release sperm before females lay their eggs and in territory defense. Defending young does not represent a other species, females provide care even when males large energetic or time increase over and beyond the cost release gametes last. of defending a territory. Moreover, male reproductive rates are not necessarily curtailed by providing care, because A third hypothesis, known as the association hypothesis, is multiple females may spawn with a single male. This is currently favored for explaining the preponderance of especially true when females are attracted to particularmale care in fishes. The simple notion is that the sex with spawning areas because of reduced offspring mortality. Infact, in some fish species, females are most

attracted to males that already have eggs in their nests. In contrast to males, the provisioning and protection of young can severely impact female growth and fecundity. Therefore, male care is more common in fishes because the costs of providing care are lower for males than for females.

6.9 SUMMARY

Fishes are a group of aquaticchordates that have gills and lack limbs. The term fish is an informal label that does not refer to a single taxonomic group but instead is used as a general term to refer to various aquatic craniate animals including hagfish, lampreys,cartilaginous fishes, bony fishes and lobe-finned fishes. Fish do not include tetrapods (four-limbed vertebrates such as amphibians, reptiles, birds and mammals) and for this reason the group is considered to be paraphyletic.Most fish breathe using gills. They take water in through their mouth and push it out through their gills. As the water enters the fishe's mouth, it is rich in oxygen. When it passes through the gills, the oxygen is absorbed from the water as it flows through the capillary-rich gill filaments. At the same time, the waste product of respiration--carbon dioxide--is released into the water before it is then released from the gills through openings on either side of the pharynx.Most fish are cold-blooded animals that have a streamlined body that is adapted for efficient movement in water. There are exceptions to both of these rules though. Tuna, swordfish and a few shark species are warm-blooded, not cold-blooded. Rays are flat-bodied fish that not streamlined. They move through the water at a slower pace by undulating their broad pectoral fins.The development of jaws in the evolutionary history of fish represents an important step. Jaws enabled fish to catch and eat a wide variety of food including marine plants and animals. Food is broken down in the esophagus and digested in the stomach and digestive tract. Waste is excreted in the form of ammonia. Most fish move using pairs of muscles on either side of their backbone. These muscle pairs contract in sequence such that the fish moves in S-shaped wave through the water. Fish have a streamlined body that enables them to move efficiently through the water. Many species have a swim bladder, a organ that contains air and enables the fish to control its buoyancy in the water. There are many animals whose name includes the term fish but that are not true fish. Such organisms include crayfish (a group of crustaceans), cuttlefish (a group of cephalopod), starfish (a group of echinoderm), and jellyfish (a group of invertebrates).A group of fish that is loosely organized, with each individual fish foraging on its own independently is called a shoal. A tightly organized group of fish that moves and feeds as one coherent unit is called a school. The largest living fish is the whale shark which grows to 60 feet in length and over 20 tons. The smallest known living fish is *Paedocypris progenetica*, a

species that belongs to the carp family and is native to the Indonesian island of Sumatra. It is less than 8 mm in length.

6.10 *SELF ASSESSMENT QUESTIONS*

1. A fish is characterized by the presence of_____
   (a) Paired fins.
   (b) Pharyngeal gills
   (c) Dermal Scales.
   (d) All of these.

2. Branch of biology dealing with study of fishes _____
   (a) Fishery.
   (b) Toxicology.
   (c) Ichthyology
   (d) Piscology.
3. Which one is true fish _____
   (a) Jelly fish.
   (b) Cuttle fish.
   (c) Silver fish.
   (d) Flying fish.
4 Body in Scoliiodon is covered by:
   (a) Dermal plates
   (b) Cycloid scales
   (c) Playcoid scales
   (d) Ctenoid scales
   .
5. Anadromous fishes move_____
   (a) From sea to fresh water.
   (b) From sea to estuary.
   (c) From river to sea
   (d) From estuary to sea
6. The fish famous for parental care is_____
   (a) Sea-horse.
   (b) Labeo rohita
   (c) Gambusia.
   (d) Scolidon.

7. A catadromous fish migrates from_____
   (a) River to sea

(b) River to estuary.
(c) Sea to river.
(d) Deep sea to surface water

8 Scoliodon is:

(a) Marine herbivorous
(b) Freshwater carnivorous
(c) Marine ,carnivorous and predator
(d) Freshwater ,omnivorous

9 The accessory organ of respiration in lung fishes is:

(a) Swim bladder
(b) Gills
(c) Lungs
(d) Urinary blodder

10 Swim bladder is absent in

(a) Teleost
(b) Acanthodians
(c) Placoderm
(d) Elasmobranchs

Answers

1 (d) 2 (c) 3 (d) 4 (d) 5 (c) 6 (a) 7 (a) (c) 9 (c) 10 (d)

6.11 TERMINAL QUESTION ANSWERS

1. Describe habit, habitat and distribution of Scoliodon.
2. Describe the Nervous system of Scoliodon.
1. Give the General characters and classification of fishes.
2 .Describe the paired and unpaired fins and types of scale in fishes.
3. Describe the parental care in fshes with suitable examples.
4. What is migration ? Describe migration in Fishes.

Write short notes on:

1. Yolk-sac placenta.
2. Parental care.
3. Internal fertilization.
4. Homocercal tail.
5. Heterocercal tail.
6. Diphycercal tail.
7. Shagreen.
8. Cycloid scale.
9. Placoid scale.
10. Causes of fish migration

6.12 REFERENCES

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UNIT 7: AMPHIBIAN

CONTENTS

7.1 - OBJECTIVES

- To understand the systematics and functional morphology of various groups of amphibians.
- To study their characters and classification upto order level.
- To study the detailed structure and disection of a Frog, *Rana tirina*.
- To study the parental care, Neoteny and Paedogenesis in amphibians.

7.2 - INTRODUCTION

Amphibians are ectothermic, tetrapod vertebrates of the class **Amphibia**.Modern amphibians are all Lissamphibia. They inhabit a wide variety of habitats with most species living in terrestrial or aquatic ecosystems. Amphibians typically start out as larvae living in water, but some species have developed behavioural adaptations to bypass this. The young generally undergo metamorphosis from larva with gills to an adult air-breathing form with lungs. Amphibians use their skin as a secondary respiratory surface and some small terrestrial salamanders and frogs lack lungs and rely entirely on their skin. They are superficially similar to reptiles but, along with mammals and birds, reptiles are amniotes and do not require water bodies in which to breed. With their complex reproductive needs and permeable skins, amphibians are often ecological indicators and in recent decades there has been a dramatic decline in amphibian populations around the globe.

The earliest amphibians evolved in the Devonian period from Sarcopterygian fish with lungs and bony-limbed fins, features that were helpful in adapting to dry land. They diversified and became dominant during the Carboniferous and Permian periods, but were later displaced by reptiles and other vertebrates. Over time, amphibians shrank in size and decreased in diversity, leaving only the modern subclass Lissamphibia. The three modern orders of amphibians are Anura (the frogs and toads), Urodela (the salamanders), and Apoda (the caecilians). The number of known amphibian species is approximately 7,000, of which nearly 90% are frogs. The smallest amphibian (and vertebrate) in the world is a frog from New Guinea (*Paedophryne amauensis*) with a length of just 7.7 mm (0.30 in). The largest living amphibian is the 1.8 m (5 ft 11 in) Chinese giant salamander (*Andrias davidianus*), but this is dwarfed by the extinct 9 m (30 ft) *Prionosuchus* from the middle Permian of Brazil. The study of amphibians is called batrachology, while the study of both reptiles and amphibians is called herpetology.

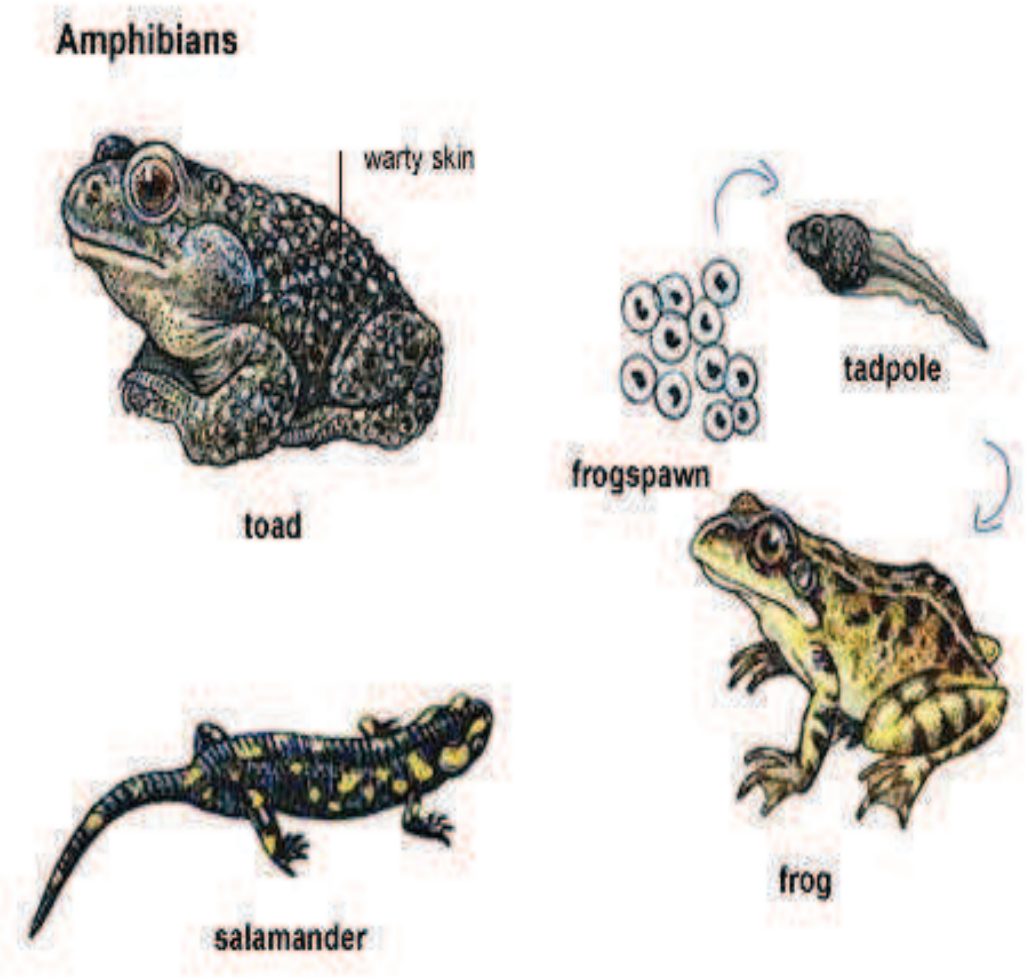


Fig.7.1 Some of the AmphibianS

7.3 GENERAL CHARACTERS AND CLASSIFICATION

7.3.1 GENERAL CHARACTERS OF AMPHIBIANS

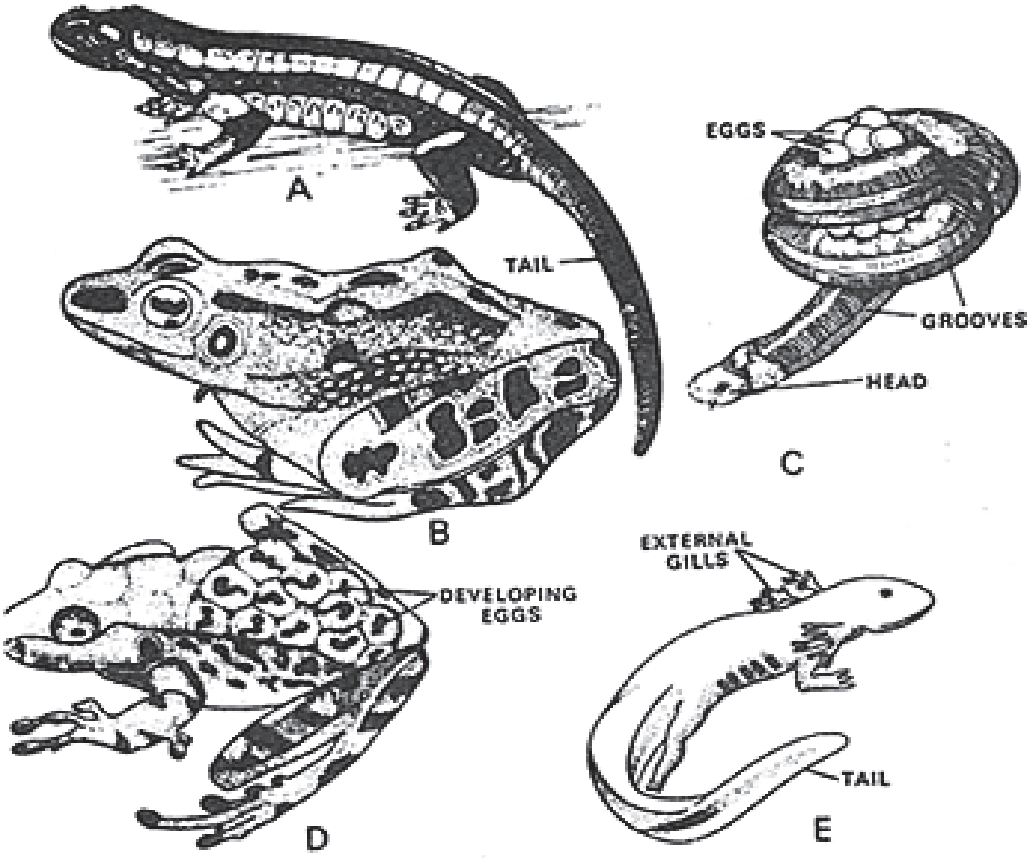
a) Amphibians are cold blooded vertebrates which can live on land and in water.
b) Amphibians show four limbs with which they can swim in water and jump or walk on the land, (In apoda limbs are absent.)
c) In Amphibians, exoskeleton is absent.Eg. in Apoda, However in some small cycloid scales are present.

d) In Amphibians the adult animals lungs are present. Gills are absent. But In some adult urodelans the gills are present.

e) Amphibians can respire by skin.

f) The Amphibians skull is dicondylic.

g) Ribs are absent in Amphibians.



h) The body divisible into head and trunk Tail is present in, urodela.

i) Digestive system is well developed. A well developed liver Is present

j) External ear is absent. Middle and inner ears are present in the middle ear columella auris is present.

k) Heart is 3 chambered with 2 auricles and 1 ventricle The blood contains R.B.C. They are nucleated. They contain haemoglobin.

l) Blood vascular system contains hepatic and renal portal systems.

m) Kidneys are mesonephric. Urinary bladder is present. It stores urine.

n) Central nervous system is well developed. The brain occupies completely the cranial cavity. The brain is divided into fore, mid and hind brains. Brain continuous as spinal cord.

o) 10 pairs of cranial nerves arise.

p) Sexes are separate.

q) Male and female can be indentified – (sexual dimorphism is clear)

r) A larva stage may be present.

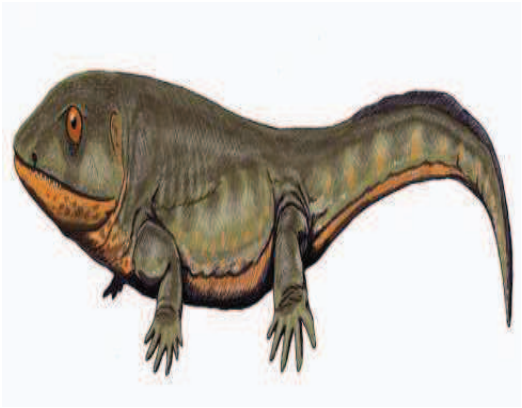
s) Eggs are telolecithal, cleavage is holoblastic and unequal.

7.3.2 CLASSIFICATION UP TO ORDER LEVEL

Amphibians are groups of animals which attain the transitional mode of life between aquatic and terrestrial mode. From phylogenec history this class is placed in between the Fishes and Reptiles.

According to G.K. Nobel, class Amphibia is divided into two sub-classes one includes all extinct orders and the other includes the living members.

(A) SUB-CLASS-I: STEGOCEPHALIA (Extinct).



i) Limbs are pentadactons. (Five digits)

ii) Skin covered by scales and bony plates.

iii) Skull with a solid bony roof which possess two pairs of opening for eyes and nostril.

iv) They were found in Permian and Triassic period of geological time scale.

This sub-class is further grouped into three orders

(I) Order-I - Labyrithodontia:

(i) These groups of amphibians are the most primitive and oldest known tetrapods.

(ii) These are called as stem Amphibia.

(iii) Both water and land forms.

(iv) Show characteristic of Crocodiles and Salamanders.

(v) Skull completely roofed over by bones.

(vi) Much bony element present in their skulls than the modern amphibia.

(vii) Enlarged teeth with greatly folded dentine found in both the jaw.

(viii) They lived from lower Carboniferous era to the Triassic periods.

Example: - Eryops, Ecogyrinus, Palaeogyrinus, Cyclotosaurus.

(II) ORDER - II - PHYLLOSPODYLI:

(i) Small salamander like body.

(ii) Head large and flat.

(iii) Vertebrae tubular.

(iv) Notochord and spinal cord housed in same cavity.

(v) Well marked transverse process and stout ribs.

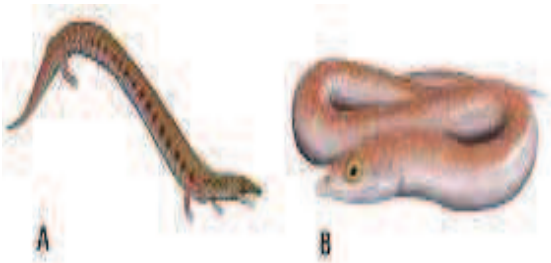
(vi) Pubis cartilaginous.

(vii) Four finger in limbs with five toes.

(viii) Coracoids cartilaginous.

(ix) Skull roof possess separate quadratojugal and lacrimal process.

(x) Lived during Carboniferous to Permian period.



(xi) Considered as the ancestors of modern Salientia and Urodela.

Examples:-**Branchiosaurus** (Ichthyostega)

(III) ORDER – III – LEPOSPONDYLI:

(i) Small samander like or el like.

(ii) Vertebrae cylindrical, each made up

Of single piece.

(iii) Neural arch and centrum continuous.

(iv) Ribs articulating intervertebrally.

(v) Regarded as the ancestors of modern Gymnophiona.

(vi) Lived between Carboniferous and Permian period.

Example: - **Diplocaulus, Lysorophus.**

(B) SUB-CLASS – II – LISSAMPHIBIA:

i) This sub-class includes all modern living amphibians.

ii) Dermal bony skeleton over skin absent.

iii) Teeth small and simple.

This sub-class includes three orders of living amphibians.

(I) ORDER-I: Gymnophonia or Apoda :

(i) These are blind, limbless, burrowing in nature.

(ii) Elongated worm like body.

(iii) Tail short or absent, cloaca terminal.

(iv) In some cases dermal scales embedded in skin which is transversely wrinkled.

(v) Skull compact and roofed by bone.

(vi) Girdles absent in limbs.

(vii) Body is grooved transversely.

(viii) Eyes without eye lids.

(ix) Presence of protrusible tentacles between eyes and nostril.

(x) Males possess protrusible copulatory organ.

(xi) Fertilization internal in Typhlonectess but usually external.

(xii) There are about 55 species.

Example: Ichthyophis, Typhlonectess, Ureacotyphlus etc.

(II) ORDER – II – Urodela or Caudate:

(i) Lizard like amphibians with distinct tail.

(ii) 2 pairs of equal limbs.

(iii) Skin without scales and tympanum.

(iv) Males without copulatory organ.

(v) Larva aquatic.

(vi) Teeth present in both jaws.

(vii) Usually oviparous.

(viii) Body with distinct head, trunk & tail.

Example: Ambystoma, Triton, Salamandra.

(III) ORDER-III –SALIENTA or ANURA:

(i) They lack tails in adult.

(ii) Hindlimbs larger, stout, highly muscular adopted for leaping, jumping and swimming.

(iii) Adults without gills, but these are present in larva.

(iv) Eye lids well developed.

(v) Ribs absent, reduced to pectoral gridle.

(vi) Tympanum present.

(vii) Skin is loosely fitted to body, wall skin without scales.

(viii) Fertilization usually external.

(ix) Fully metamorphosed without neotonic forms.

Example: *Rana, Bufo, Pipa , Alytes, Xenopus, Hyla*, etc.

7.4 GENERAL STUDY OF RANA TIGRINA

Frog is an amphibian, living both on land and in water. The amphibians are the first group among the chordates that lived outside water. They are cold-blooded vertebrates having two pairs of limbs-tetrapods. They have smooth and moist skin. *Rana tigrina* is studied in detail because of its easy availability. Its structural details are very similar to other animals.

Classification:

Phylum: Chordata
Subphylum :Gnathostomata
Superclass: Tetrapoda
Class :Amphibia
Order: Anura
Genus : *Rana*
Species: *tigrina*

Habitat: They are cosmopolitan in distribution. They are usually found in fresh water ponds, rivers, ditches, under-stones and in damp places except in arid parts of the country. They remain active in spring and rainy season. And become inactive in summer. Frog is usually known as "Indian bull frog" because of its large size and loud voice.

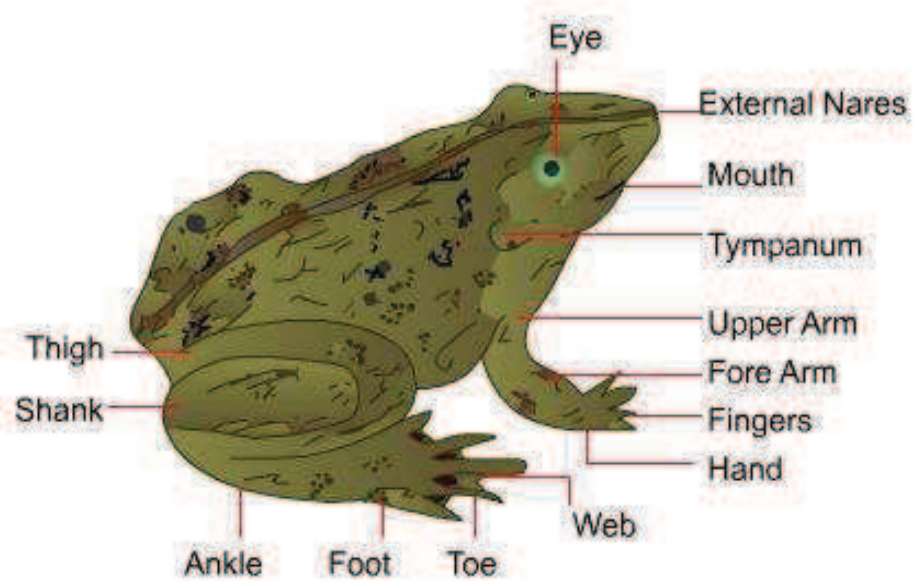


Fig 7.*1 Rana tigrina*

Habits: Frogs characteristically have smooth skin, strong hind legs for leaping and webbed feet. Most reproduce in water, laying eggs that develop into larvae (tadpoles). It shows following habits:
a) Resting: Frogs rest on land in a squatting posture. They keep their short fore limbs upright and the long hind limbs fold inside the body. On any disturbance they suddenly jump in water by extending their hind limbs to escape from enemies.
b) Feeding: Frog is a carnivorous animal. It feeds on earthworms, insects, spiders, snails and tadpoles. However, tadpoles feed on aquatic plants, i.e. they are herbivorous. The frog is a cold-blooded or poikilothermic animal which means its body temperature fluctuates with that of the environment. Therefore it cannot bear very cold or very hot temperature. The frog needs hibernation (winter-sleep) and aestivation (summer sleep) to tide over the unfavourable conditions.
c) Hibernation (winter sleep): During winter the frogs bury themselves deep into the mud and take rest. This is called winter-sleep or hibernation. In winter the metabolism is slow and its temperature falls down. Therefore, the frogs become sluggish and inactive. Frog does not respire with the lungs, respiration takes place through skin. The general vital activities of the animal are so low that very little expenditure of the energy is needed to maintain life. Frog does not take any food but consume energy stored in their body in the form of glycogen. They remain inside till the next spring. Similarly frogs need

summer-sleep or aestivation to tide over the drought. They bury themselves in the soft mud and become inactive and sluggish.

d) Locomotion: Locomotion in frog takes place by two methods: (i) leaping on land and (ii) swimming in water.

i) Leaping: While resting on land, the frog keeps its short fore limbs upright and the long hind limbs folded like "Z". The frog jumps by a sudden extension of the hind limbs which act like springs throwing the body up into air. The fore limbs are used to hold up the anterior part of the body and to manipulate the direction, foe which it adjusts its body in a new direction before each leap. A frog may leap a distance of 1.5 to 2 meters in a single jump.

ii) Swimming: The frog swims in water by alternately flexing and extending its hind limbs. As the animal starts to swim the legs are extended quickly. During their backward strokes, the toes are spread apart and the broad webs push against water, moving the body forward. The fore limbs serve two purposes: they help in propelling the animal to some extent and in guiding the direction of the movement.

e) Croaking: The characteristic sound made by frog during breeding season is called croaking. It is a mating call. It is produced by forcing air from lungs over vocal cords into mouth cavity and back again. It is louder in males than in females due to presence of vocal sacs. Male frog croaks to attract the female frogs for copulation.

f) Breeding: Frog breeds during rainy season from the end of June to September. During rainy season male frogs croak to attract females for copulation. It is a mating call. Copulation takes place in shallow water, where they lay down eggs for fertilization. There is no parental care.

External Features:

Shape and Size: The body of the frog is bilaterally symmetrical. It is spindle shaped, pointed anteriorly and rounded posteriorly. It is some what dorsoventrally flattened and streamlined which offer least resistance during swimming. A light yellow line runs mid dorsally from tip of the snout to the

cloacal aperture, called the mid-dorsal line. It measures about 12 to 18 cm in length and 5 to 8 cm in width.

Skin and Colour: The skin forms the outermost layer of the body. It is loose, smooth , moist and slippery without any derivatives like scales, feather and hairs. It is attached to underlying muscles only at intervals by connective tissue septa At places the skin is thrown out into a number of folds extending from behind the eyes. These folds are called dermal plicae. On the dorsal side the colour of the skin is dark-green with patches of black colour, while it is pale yellow on the ventral side

Division of Body: The body is divided into two regions: the head and the trunk. The neck and tail are absent. Tail is present only in larval stage. The head and trunk are broadly jointed.

Head: The head is triangular in shape jointed directly to the trunk. It is narrow in front and broad behind. The anterior narrow blunt end is known as snout. It bears mouth, nostrils, eyes and tympanum.

Mouth: A wide opening called mouth is situated at the anterior end of the snout. It is a wide transverse opening, which extends nearly from one ear drum to the other. It is bounded by upper and lower jaws. It has no lips and cheeks.

Nostrils: There is a pair of small openings called nostrils or external nares on the anterior tip of the snout. Each narial opening is guarded by a membranous valve and leads into the buccal cavity through internal nares. They allow only air to pass in or out during breathing.

Eyes: There are two large prominent eyes on each side of the head. The eyes are round, protuberant and dorso laterally placed, on the top of head. As the eyes are large, protuberant and laterally situated, they fulfill the absence of neck and frog can see all around without moving the body

Tympanum: Behind and below the eye, on either side, there is a circular obliquely placed membrane, the eardrum or the tympanum. There is no external ear or pinna. The tympanum receives sound vibrations from the environment. In male frog, under the mouth, there is a pair of bluish patches of skin called vocal sacs. The vocal sacs help in croaking. The male croaks more loudly than the female. The

croaking of frogs appear to be a call for mating during rainy season.

Trunk: The posterior portion of the body consists of somewhat flattened trunk. Its back is raised in the middle as a characteristic sacral prominence or hump. At the posterior end, the trunk contains an opening, the cloacal aperture between the two legs. It is a common aperture through which faeces, urine and reproductive products (sperms and ova) are discharged.

Limbs: The limbs are lateral in position. The trunk bears two pairs of limbs. The fore limbs are shorter and arise anteriorly from the trunk just behind the head. It consists of three distinct parts: the upper arm (brachium), the forearm (antebrachium) and the hand or the manus. The hand consists of a palm and four fingers without web. The base of first inner finger in male frog has a dark rough swelling known as nuptial or copulatory pad. Specially in breeding season the copulatory pad becomes very thick and sticky.

Sexual Dimorphism:

Frog shows sexual dimorphism i.e. the male and female can be distinguished by their morphological characters:

i) The males are usually smaller and darker in colour than the female.
ii) Males are slimmer while the females are stouter.
iii) The male frog has vocal sacs which help in croaking loudly. The female has no vocal sac.
iv) The forelimbs in male frog possess swollen copulatory pad on the first inner finger. In breeding season the copulatory pad becomes very thick and sticky. It helps in grasping the female. It is not found in female.

Functions of the Skin:

1) The skin provides a protective covering over the body. it also protects the frog against the invasion of many germs.

2) It exhibits protective colouration to the body.
3) The mucous glands secrete a colourless watery fluid that keeps the skin moist and sticky.

4) The moist surface of skin helps in exchange of respiratory gases between the environment and the body. Thus, it takes part in respiration.

5) The keratinized cells shed off periodically and helps in removing certain wastes of the body.

6) The poison glands secrete poisonous substance which serves to protect it from enemies.

7) Frogs never drink water through mouth but they absorb water through their skin.

8) It acts as an important sensory organ.

9) The membrane bones usually found in the skull are formed of the connective tissue sheaths of dermis.

10) The skin of the embryos of frog produces hatching enzymes, which help in hatching by dissolving the egg membranes.

DIGESTIVE SYSTEM

The digestive system of frog consists of organs, which are concerned, with capturing of food (ingestion), absorption with the help of certain enzymes, absorption of the digested food, and finally removal of the waste food. Hence, digestive system is divided into 3 headings.

1. Alimentary canal
2. Digestive gland

3. Physiology of digestion

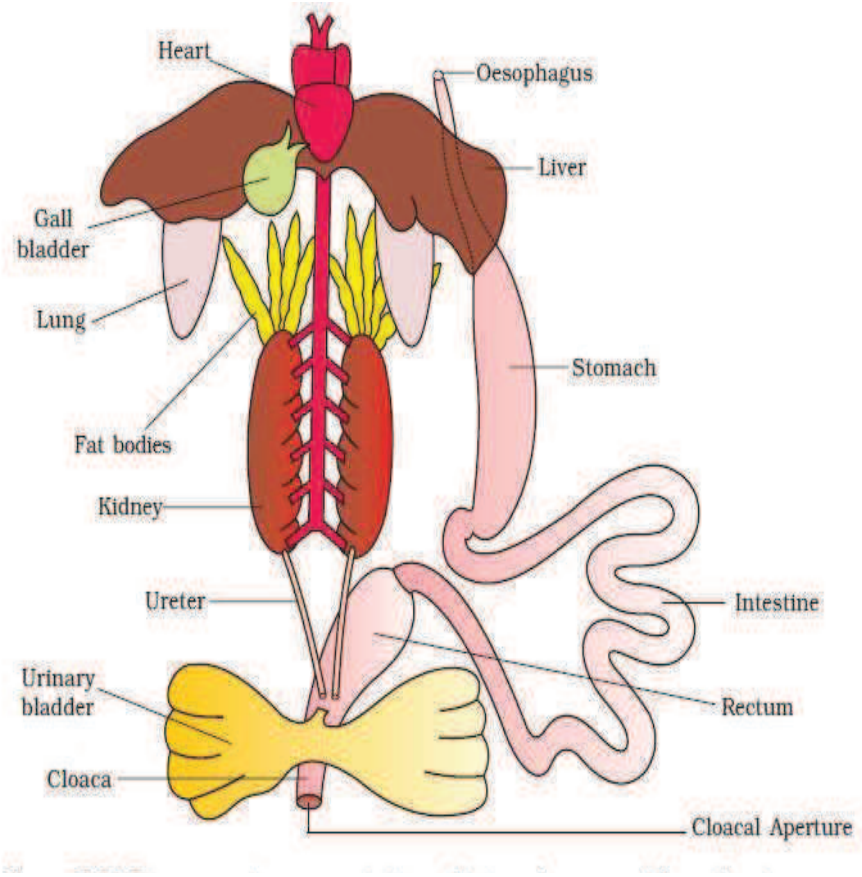


Fig.7.2 Digestive system in frog

Alimentary canal:- it is long, coiled tube which starts from mouth to anus (cloacal aperture). It consists of following organs.

Buccopharyngeal cavity

The buccal cavity and pharynx together is called bucco-pharyngeal cavity. Buccopharyngeal cavity lies between upper jaw and lower jaws. Upper jaw is immovable but lower jaw is movable. **Teeth** – there are two types of teeth. Maxillary teeth- they are found in upper jaw. They are polyphyodant (replaceable teeth) and homodont (all teeth are similar in size). Vomerine teeth- they are

present on either side of roof buccopharyngeal cavity. They help to capture prey and prevent the captured pre from slipping out.

Tongue: It is thick, fleshy, and muscular and bifurcated (bifid). The tongue is protrusible i.e. tongue can be thrown out and retracted. It arises from in front of lower jaw. The tongue secrets a kind of sticky substance so that insects or prey coming neat sticks in tongue.

Vocal sac: In male frog on either side of the tongue on the lower jaw there are two pores called vocal sacs, which produce croaking sound.

Pharynx: Posterior part of buccopharyngeal cavity is called pharynx, which opens into oesophagus.

Oesophagus: It is broad, short muscular tube which opens into stomach.
Stomach: The stomach is large, thick walled muscular bag. Anterior part of stomach is called cardiac part and posterior part is called pyloric part. It is internally folded. It stores ingested food. Posterior part consists of pyloric constriction through which food is slowly passed.

Intestine: It is long, coiled part which starts from pyloric constriction. Intestine is divided into two parts.

Duodenum: it is c shaped structure, 3-5 cm long where hepatopancreatic duct opens.

Ileum: it is coiled part. It is about 20-25 cm long. Ileum is internally highly folded. Folding s is called villi, which increase absorptive surface.

Rectum: (large intestine): rectum is short, broad tube 4-5 cm long. It opens outside through cloaca and the opening id called cloacal aperture. The rectum stores undigested food for short time. Internally rectum is also folded.

Physiology of digestion

- Frog is insectivorous (insects eating).
- The prey is captured by the action of tongue and swallowed without mastication.
- The food becomes lubricated by mucous secreted by mucin gland. (salivary gland is absent). When the food reaches the stomach the chemical digestion starts.

In stomach

- The gastric glands present on stomach wall secrete HCl and the Pepsinogen enzyme.
- The food is mixed with HCl. the HCl kills the bacteria, and softens the hard food.
- The pepsinogen is inactive enzyme. But in presence of HCl, it becomes active and then it is called Pepsin which digests protein into proteases and peptones.
  Pepsinogen————————-Pepsin
  Protein————————Proteoses and peptones
- The food becomes creamy fluid called Chyme. From the pyloric constriction, the chyme slowly moves towards duodenum.

In Duodenum

The food is mixed with bile and pancreatic juice.

Bile: It is a kind of alkaline juice secreted by liver. It has mainly two functions like It neutralizes the acidic food and It emulsifies fat i. e. the fat droplets are broken into fine droplets and mixes with the food.

Pancreatic Juice: It is also a kind of juice secreted from the pancrease. It contains following enzymes

Trypsinogen – In presence of enterokinase it is converted into trypsin and the trypsin digests the protein into peptones and polypeptides.

Trypsinogen——————Trypsin

Protein———————-Peptones and polypeptides.

Amylase – It digests the carbohydrate into maltose.

In Ileum

The food is mixed with intestinal juice in ileum, which contains following enzymes.

Eryption: It digests peptones and proteoses into amino acids.

Peptidase: It digests peptides into amino acids

Sucrase: It digests sucrose into glucose.

Maltase: It digests maltose into glucose.

Lactase: It digests lactose into glucose.

Nucleotidase: It digests nucleic acid into nucleotides.

Absorption

The completely digested food material contains glucose, amino acids, fatty acids, glycerols etc. The simple molecules like water and minerals are not required to digest. All these simple compounds are now absorbed through the villi of intestine. There are two methods to absorb food materials. The food materials are absorbed by diffusion or osmosis through the villi and are mixed into the blood around the intestine. It is slow process and food molecules pass into blood from the high concentration in lumen of intestine. This method is called passive method. There is another method of absorption i.e. active method. It is fast and the food molecules are absorbed by using energy against concentration gradient from the lumen of intestine into the blood. The energy used in this method is ATP. Hence, all the food materials are absorbed completely into the blood. The remaining undigested and unabsorbed materials are stored in rectum for short time and ultimately passed out through the anus.

RESPIRATORY SYSTEM

The process of gaseous exchange (O_2 and CO_2) and utilization of oxygen to breakdown food to release energy is called respiration. The process of respiration involves three stages.

External respiration

It also refers to breathing. In this process, the O2 is taken into the body and the CO2 is thrown out from the body into the environment.

Internal respiration

It refers to utilization of O2 to break down food to release energy and release of CO2 during the process.

Transport of gases

It refers to transportation of O2 from the respiratory surface to the cell and tissues and the CO2 from cell and tissues to the respiratory surface. There are three types of respiration in frog

1. Cutaneous respiration

- The respiration through skin is called contineous respiration.
- The contineous respiration occurs in hibernation and aestivation and in water.
- The skin of frog is thin and vascularised (skin is supplied with fine blood vessels).
- The skin always becomes moist by mucous secreted from the mucous glands.
- Due to moist skin, the oxygen from the environment diffuses into the blood through skin and the carbon di oxide diffuses out from the blood into the environment.

2. Buccopharyngeal respiration

- The respiration through the buccopharyngeal cavity is called buccopharyngeal respiration.
- The buccal cavity consists of moist mucous membrane and richly supplied with blood vessels.
- The air enters into the cavity through nares and gaseous exchange takes place through the lining of buccal cavity between blood and air present in the cavity.

3. Pulmonary respiration

- The respiration through the lungs is called pulmonary respiration.
- This respiration occurs only when the need of oxygen is more during swimming and jumping.
- There is a pair of lungs. The lungs are thin walled elastic sacs. They are present within thoracic cavity on either side of heart.
- Numerous small air sacs are present in the lungs called alveoli.
- The alveoli are very thin walled and supplied by blood vessels. The air enters into the alveoli of the lungs through the external nares, internal nares, buccopharyngel cavity, glottis, laryngotrachial camber and bronchi.

Expiration:

- The process of exhaling of CO_2 is called expiration.
- The lungs get contracted. The external nare remains closed.
- The floor of the cavity is lowered and the air is drawn into the cavity from the lungs.
- The nares then open and the cavity raises and then the air is passed out through the nares.

- **Blood- Vascular System**
  Circulatory system is the system of blood, heart, and blood vessels.

1. Heart

- Heart is triangular muscular pumping organ. It is situated ventrally to the liver in the pericardial cavity.
- Heart is three-chambered.
- Upper two chambers are called auricle sand lower one chamber is called ventricle.
- Its anterior end is broader than posterior end.
- The broader part anterior is known as auricle.
- The posterior part is known as ventricle.
- The ventricle is thicker than auricle; .right auricle is larger than left auricle.

External structure of heart

Ventral view

The tubular structure is present on right side of anterior part of ventricle, which is called truncus arterious. It gives two branches called aortic trunks.

Dorsal view

There is somewhat triangular structure called sinus venosus. It opens into right auricle. The right precaval, left precaval and post caval veins open into sinus venosus.

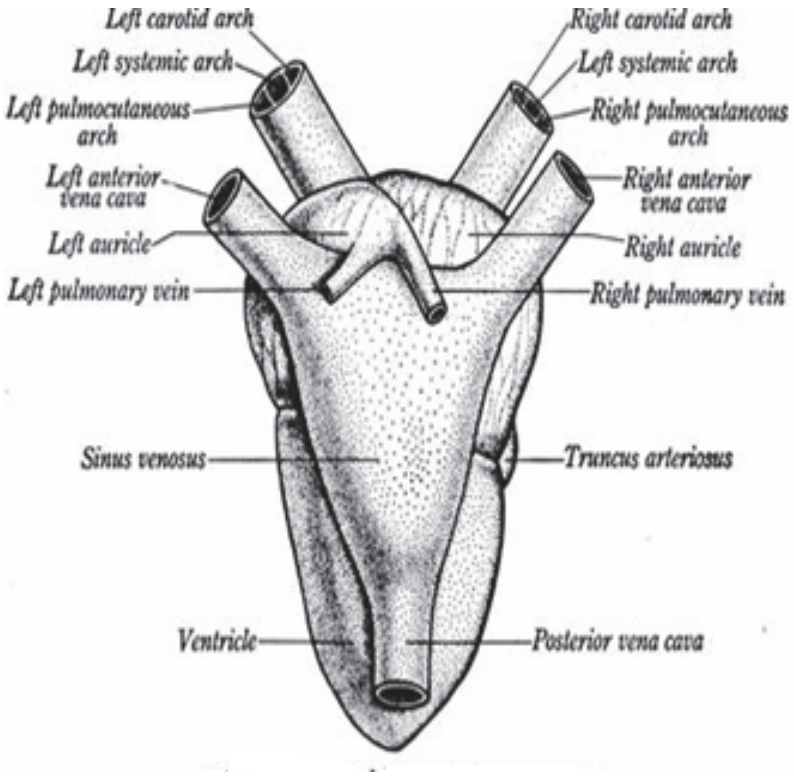


Fig.7.3 Dorsal view of Heart of Frog

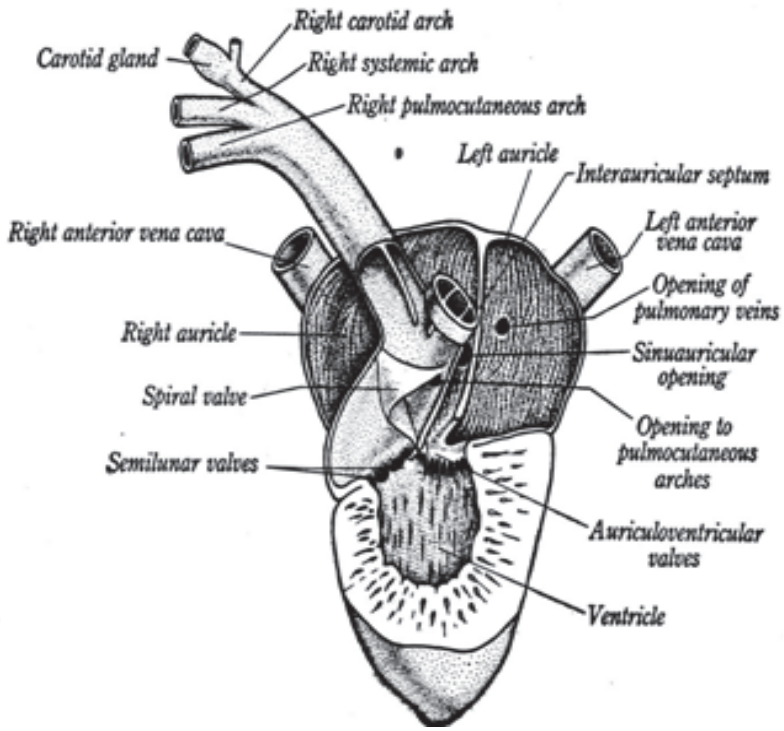


Fig 7.4 Ventral view of dissected heart of Frog

Internal structure of heart:

- Two auricles are separated by a septum called internal auricular septum.
- The right auricle bears opening of sinus venosus called sinu-auricular aperture which is guarded by valves called sinu- auricular valves.
- It allows flow of blood from sinus venous to right auricle and prevents back flow of blood.
- Left auricle bears opening of pulmonary vein without valve.
- Auricles open into ventricles by auriculo-ventricular aperature, which is guarded by four auriculo – ventricular valves.

- The flaps of these valves are connected to the wall of ventricles by chordae tendinae.
- A ventricle is thick walled and internally give in folding called trabecule.
- Ventricle opens into truncus arterious.

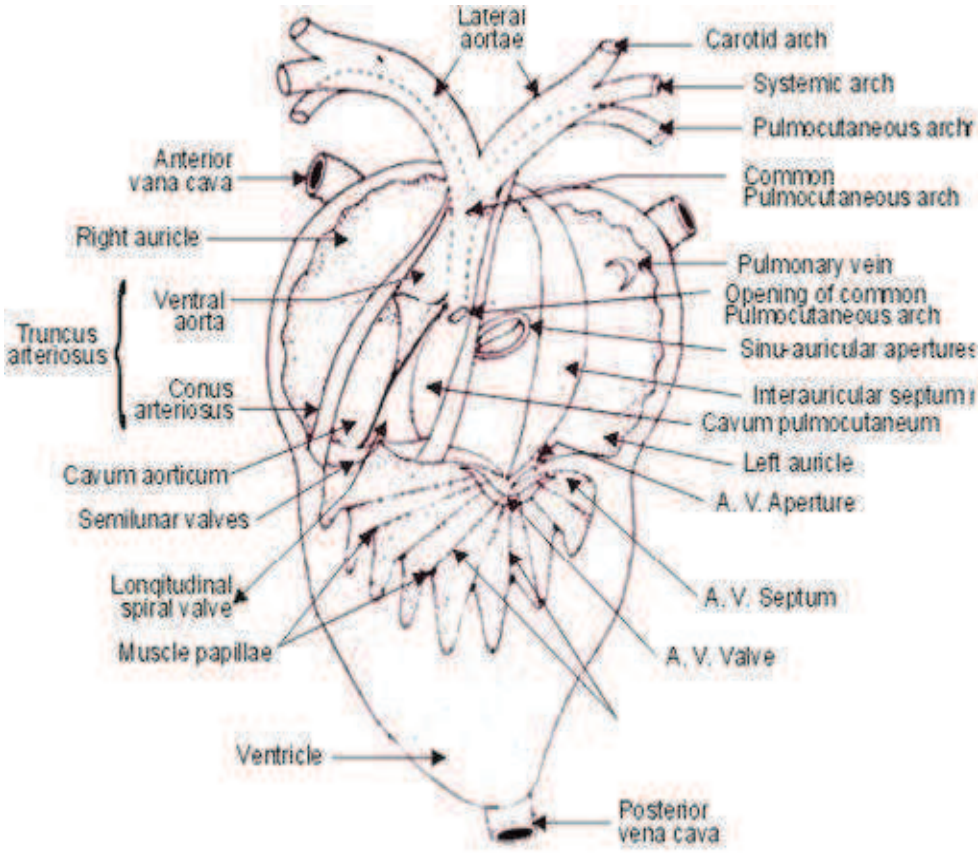


Fig.7.5 Internal structure of Heart

- The opening is guarded by four semilunar valves, which prevent backward flow of blood from truncus arterious to ventricle.
- A truncus arterious is divided into two parts at the base.

- **Arterial system of frog**

Blood vessels, which carry oxygenated blood away from heart to different part of the body, are called arteries. They constitute a system called arterial system. Truncus arterious gives two branches right aortic trunk and left aortic trunk. Each aortic trunk again divides into three branches.

a) Carotid arch:

it divides into –

Lingual artery – it supplies blood to tongue and hyoid.

Common carotid – it supplies blood to buccal cavity and brain. it consists swelling at the base called carotid labyrinth.

b) Systemic arch – two systemic arches move upward and then curve backward to join each other behind the heart to form dorsal aorta before meeting each other each systemic arch gives-

Oesophageal artery – it supplies blood to osephagus.

Occipito vertebral artery – it supplies blood to head and vertebral column.

Subclavian – it supplied blood to shoulder and forelimb. From the junction of two systemic arches coeliaco – mesenteric artery arise which gives following branches.

Coeliac artery arises and gives two branches –

Hepatic artery artery – it supplies blood to liver.

Duodenal artery –it supplies blood to duodenum.

Intestinal artery – it supplies blood to small intestine (ileum).

Spleenic artery – it supplies blood to spleen (meeting place of ileum and rectum).

Posterior mesenteric artery- It is Long Branch and supplies blood to the rectum.

The dorsal aorta runs backward and gives following branches-

Gonadial artery – it supplies blood to testes and ovary.

Renal artery- it supplies blood to kidney. At the end, the dorsal aorta runs posterior and bifurcates into right and left common iliac arteries. Each of iliac arteries gives

Femoral artery – it supplies blood to hip and thigh.

Sciatic artery – it supplies blood to lower region of hind legs.

Epigastric artery- it supplies blood to urinary bladder.

c) Pulmo-cutanous arch– it divides into

Pulmonary artery – it receives deoxygenated blood from different parts of the body and open

into lungs.

Cutanous artery- it supplies oxygenated blood to skin.

Venous System of frog

Blood vessels, which carry the deoxygenated blood from different parts of the body to the heart, are called veins. They constitute a system called venous system. Venous system of frog can be studied under two headings

7.5 GENERAL TOPICS

7.5.1 PARENTAL CARE IN AMPHIBIA

Parental care may be defined as all activities that are directed by an animal towards the protection and maintenance of its own offspring or those of a near relative.

By comparison with birds and mammals, amphibians generally have been thought to exhibit little parental care. However, in recent years both field and laboratory studies have provided evidence for an astonishing array of parental care in amphibians. Parental care may be defined as any behavior exhibited by a parent toward its offspring that Increases the offspring's chances of survival (Trivers. 1972); this investment may reduce the parent's ability to invest in additional offspring. Among amphibians, parental care Includes attendance of the eggs, transportation of eggs or larvae, and feeding of larvae.

Parental care is associated only with those species that place their eggs in single clusters, never with those that scatter their eggs in aquatic situations. Nest construction, either prior to or during opposition, is not considered to be parental care, although in some species that construct nests, one parent may attend the eggs. Likewise, the retention of eggs in the oviducts, even though nourishment is provided to the developing young, is not considered to be parental care.

There are various ways by which the parental care is manifested in amphibians.

1. Selection of Site:

Some amphibians lay their eggs in safe and moist land, very near to water.

- *Rhacophorus schlegli* of Japan, lays eggs in a hole on muddy bank of river or pond with foamy mucus cover to prevent the eggs from drying.
- In *Gyrinophilus* the eggs are laid under the stones in stream. Sometimes, the eggs are taken up on the body.
- In case of *Hylodes*, eggs are laid on the under surface of leaves hanging above water.
- In *Triton* the eggs may be fixed with the aquatic weeds by glues.

2. Frothing of Water:

- In *Rhacophorus maculates*, after the eggs are laid, surrounding water is made frothy by the limb movements, which prevent the eggs from desiccation and escaping from the eyes of the predators.

3. Defending Eggs:

- Males of green frog *Rana clamitans* defend their eggs by not allowing small sized intruders in their territories.
- Males of *Mantophryne robusta* holds with hands cluster of eggs in
- gelatinous envelop.

Fig 7.5 Defending of Egg

4. Formation of Nests:

Some amphibians build nests for deposition of eggs.

- **Mud Nest:** *Hyla faber* digs small holes in the mud for deposition and development of the eggs.
- **Leaf Nest:** In a South American tree frog *Phyllomedusa hypochondrales*, margin of the leaves are folded and glued together which acts as nest for the eggs.
- **Shoot Nest:** *Triton* construct the nest by fixing the shoots with a gelatinous secretion.

5. Direct development:

Some terrestrial or tree frogs, like *Hylodes* and *Hyla nebulosa*, the eggs hatch directly into tiny juveniles avoiding predator attach and larval mortality.

6. Carrying eggs over the body

i) Coiling around eggs:

- ✓ *Amphuima, Ichthyphis* females after laying eggs guard them by coiling body till the eggs hatch.
- ✓ In *Megalobatrachus*, the males perform the same function.

ii) Transferring tadpoles to water:

- ✓ *Phylobates, Pelobates* species inhabiting tropical Africa and South America hold the newly hatched tadpoles with their mouth and transport them to water.

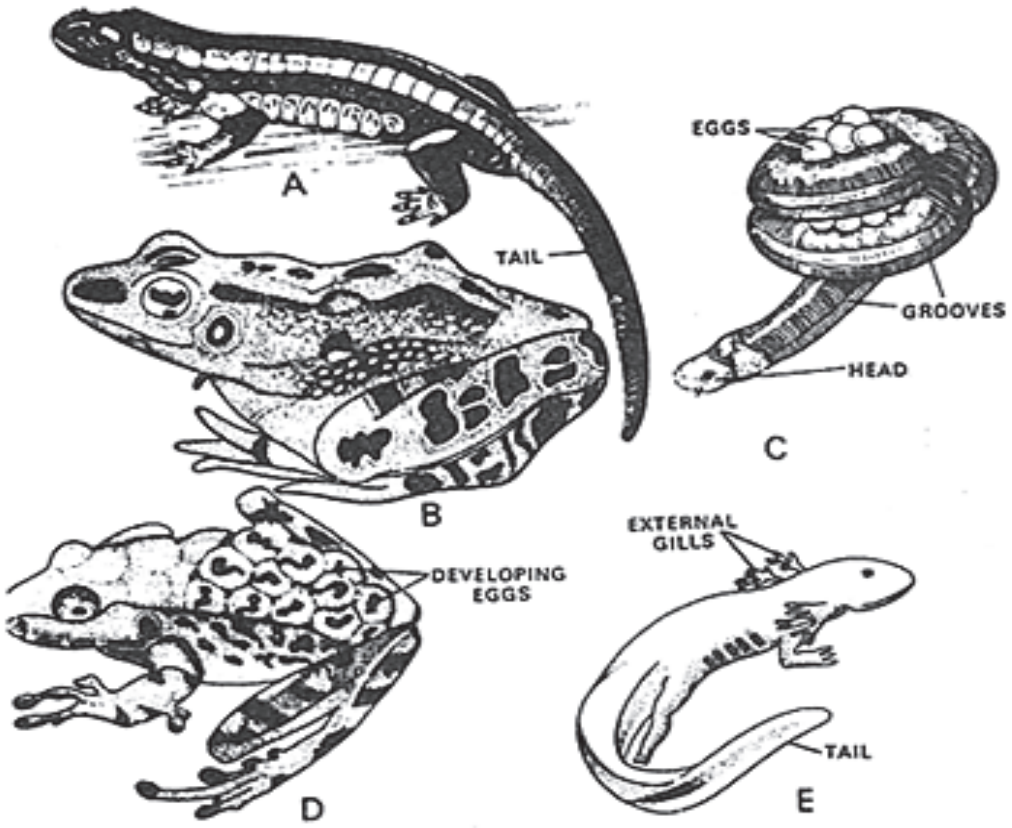
iv) Eggs glued to the body:

- ✓ Salamander *Desmognathus fuscus* females carry cluster of eggs glued to their body.

- ✓ In Sri Lankan tree frog, *Rhacophorus reticulates*, the eggs are glued to the belly of the females.
- ✓ In a European frog, *Alytes obstericans*, instead of female's parental care, the male entangles the eggs around his hind legs.

iv) Eggs in back pouches:

- ✓ In *Hyla goeldii*, the females carry the eggs on their back.
- ✓ In *Desmognathus*, the females carry the eggs and live in underground hole.
- ✓ In *Pipa pipa*, the eggs are carried by females on the back.
- ✓ In *Cryptobatrachus evansi* the dorsal skin contains many small pockets for lodging of eggs.
- ✓ In *Pipa dorsigera*, the eggs are developed in the pits on the back of the females. During breeding season, the dorsal skin becomes soft, spongy, and



vascular. Embryonic development occurs within the pits and physiological exchanges takes place between the females and the larva.

7. Carrying eggs over the body:

- In *Arthroleptis*, the larvae are attached to the males and are carried from one water body to other.

8. Organs as brooding pouches:

- South American male frog of *Rhinoderma darwinii* keeps fertilized eggs in his vocal sacs where they undergo complete development.
- In *Hylambates breviceps*, the female carries eggs in her buccal cavity.

9. Viviparity:

A special type of reproductive behavior is observed in *Salamandra atra* and *S. maculosa*. The eggs are placed inside the uterine cavity where the entire development takes place. The uterine wall functions physiologically.

7.5.2 NEOTENY

Neoteny is defined as the failure or delay of larva to metamorphose while becoming sexually mature. It is character of some amphibians.

The best example is axolotl larva of Amblystoma. It is aquatic. It has gills. It develops gonads. It lays eggs and attains large size. Amblystoma on the other hand, is terrestrial and without gills. It was considered the axtolotl as separate genera in the beginning, with the administration of thyroxine; axtlotl lost its gills and develops lungs. It metamorphosed into the adult. Metamorphosis of axolotl can be induced by reducing the water level.

Proteus.and Necturus are permanently neotenous forms. They retained the larval features and reproduce sexually like a mature animal.

Kollman has distinguished two types of neoteny:

1. **Partial neoteny**: Tadpoles of Hyla arborea, Rana escülenta during winter will show simple retardation of metamorphosis beyond the normal period.

2. **Total neoteny**: It will retain its gills and become sexually mature.

Ex Ambystoma.

Formerly full neotenic forms with external gills were considered as most primitive amphibians. But now it is believed that it is the result of secondary adaptive modifications in their larval stage.

7.5.3 PAEDOGENESIS

Paedogenesis in varying degrees is exhibited by many species of North American salamanders, particularly of the genus *Ambystoma*. On the basis of a consideration of the ecology of these species, it is proposed that paedogenesis is evolutionarily adaptive and the following hypothesis is presented. In most habitats where ambystomatid salamanders occur, they exhibit the typical amphibian life history, consisting of aquatic larvae and terrestrial adults. However, where unusually harsh conditions, such as severe temperature fluctuations, lack of suitable cover or food, and low humidity, exist on land then the adjacent aquatic habitat is more suitable for salamanders provided it is permanent and provided fish are rare or absent. Under these circumstances paedogenesis will evolve because salamanders which spend their whole lives as larvae in the water have an adaptive advantage over those which metamorphose and become primarily terrestrial. Supporting evidence for the hypothesis is based primarily on patterns of similarity in the ecology of paedogenetic species of *Ambystoma*. It is suggested that paedogenesis is most commonly reported from the western mountains because this area contains more permanent fish-free ponds than any other area of North America. Exceptions to the hypothesis are discussed and some speculation on the genetic basis of paedogenesis is offered.

7.6 SUMMARY

Amphibians are vertebrates of the taxonomic class Amphibia including animals such as frogs and toads (order Anura), salamanders (order Caudata), and caecilians (order Gymnophiona). Thought of as cold-

blooded, amphibians are ectotherms, meaning they are unable to regulate their own body temperature independently of the temperature of their surroundings. Amphibians are generally small with thin skin permeable to air and water. With few exceptions, amphibians do not actively care for their young. In general, amphibian reproduction strategy consists of egg-laying and external fertilization of a large number of eggs in a moist or fully aquatic environment. Fertilized eggs develop into amphibian larvae that live part of their lives dependent on an aquatic environment requiring gills and specialized feeding habits. Following a pattern of development unique to amphibians, amphibian larvae undergo marked changes and metamorphose into a terrestrial form that lives on land. Typically, this metamorphosis is demonstrated by loss of gills, changes in overall appearance, and changes in diet.Amphibians live in diverse habitats, often in large numbers, and play several important ecological roles. As consumers, amphibians help regulate populations of the organisms they consume, chiefly invertebrates. As prey items, amphibians are consumed by a variety of larger predators such as reptiles, birds, mammals, fish, predatory invertebrates, and other amphibians. When consumed by larger predators, amphibians transfer the energy and nutrients from amphibian prey items such as small invertebrates to larger predators.

7.7 GLOSSARY

Amphibians: A group of vertebrates including frogs, salamanders and caecilians. Amphibians usually have aquatic larvae and terrestrial adults.

Advertisement Calls: Calls used by frogs to define their territories and to attract female frogs during breeding season.

Aggressive Calls: Males usually make these calls, when other males are trying to occupy their territory or are very close to their territory.

Amplexus: Sexual embrace of amphibians; the grasping of the female's body by the males forelimbs from a dorsal position. The grip is strong, and is not released until oviposition is completed. There are two principal types: axillary (pectoral), in which the grip is just behind the forelimbs, and inguinal (pelvic), with the grip just before the hindlimbs.

Barbels: A fleshy, tubular extension of the skin, usually on the head or the neck, which appear to be sensory, probable tactile in function.

Brumation: Time period when frogs and other ectotherms become inactive in they hide in a leaf litter or take refuge in ponds to cope with the cold, dry and harsh temperatures.

Brachial: Pertaining to or located on the upper or the humeral part of the forelimb.

Call: The noise, cry, whistle or song of an anuran, usually confined to males. In a very few species, the female has a voice.

Courtship Calls: Calls that are given by both males and females just before amplexus.

Cloaca: The common chamber into which the intestinal, urinary and reproductive duct discharge their contents, opening to the outside through the anus.

Choana: Internal opening of the nasal passage in the roof of the mouth (plural: choanae).

Defensive calls: The adults of both sexes and juveniles make these calls when startled or attacked by the potential predator.

Eclosion: The emerging of an insect from the pupa case or the emergence of larva from the egg.

Guttural Resonator: Referring to the sound coming out of throat; harsh sound.

Holotype: The specimen that is the legal bearer of the name of the species, according to the International Code of Zoological Nomenclature.

Interorbital: The measurement between the eyes, usually taken across the top of the head.

Larva: An embryo which becomes self-sustaining and independent before it has acquired the characteristic features of its parents.

Labia: Lip-like structure.

Lissamphibians: A subclass of amphibians that includes all the living amphibians in the order Anura, Urodela and Apoda.

Metamorphosis: The process of changing from one form to another during development. In amphibians it is usually associated with a switch from an aquatic larval stage to a terrestrial adult phase.

Metapodials: Any one of the bones of a limb lying between the mesopodials and phalanges; the long bones making up the proximal part of a digit, lying in the fleshy part of the foot. There are two types: metacarpals and metatarsals (Peters, 1964).

7.8 SELF ASSESSMENT QUESTIONS

1. Which is limbless amphibian_____
   (a) Alytes.
   (b) Ichthyophis.
   (c) Hyla..
   (d) Phyllobotamus..

2. Frog has _____
   (a) 5 fingers & 4 toes.
   (b) 4 fingers & 5 toes .
   (c) 5 fingers & 5 toes.
   (d) 4 fingers & 4 toes .

3. Summer sleep of frog is known as_____
   (a) Aestivation
   (b) Hibernation.
   (c) Paedogenesis.
   (d) Neoteny.

4. Amphibians are characterized by_____
   (a) Presence of scaleless, glandular, moist skin.
   (b) Presence of dermal scales on the skin.
   (c) Hind webbed limbs.
   (d) Their amphibious habit living on water & land.

5. Salivary glands in frog are:

   (a) Absent
   (b) 1 pair

(c) 2 pairs
(d) 3 pairs

6 The teeth in frog are meant for:
(a) Chewing
(b) Preventing pray from slipping
(c) Tearing
(d) Cutting

7 Stomach in frog is attached to the dorsal body wall by means of a mesentery called:
(a) Oxygaster
(b) Endogaster
(c) Mesogaster
(d) Megagaster
(e)

8 The hepatopancreas duct opens into:
(a) Buccal cavity
(b) Oesophagus
(c) Stomach
(d) Duodenum

Answers

1(b) 2 (b) 3 (b) 4 (d) 5 (a) 6 (b) 7 (c) 8 (d)

7.9 TERMINAL QUESTION /ANSWER

1. Give outline classification of Amphibia.
2. Describe habit, habitat, and distribution of Rana tigrina.
3. Give diagnostic characters of class Amphibia.
4. Describe the parental care in Amphibia

Short Notes

1. Neoteny.
2. Paedogenesis.
3. Hibernation.

4. Aestivation

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UNIT 8: REPTILIA

CONTENTS

8.1 OBJECTIVE

- To understand the systematic and functional morphology of various groups of Reptilia.
- To study their characters and classification upto order level.
- To study a type of reptiles, Uromastyx.
- To get knowledge about the identification of poisonous & non poisonous snakes.

8.2 INTRODUCTION

Reptilia is a group of tetra pod comprising today's turtles, crocodilians, snakes, amphisbaenians, lizards, tuatara, and their extinct relatives. The study of these traditional reptile groups, historically combined with that of modern amphibians, is called herpetology. Birds are also often included as a sub-group of reptiles by modern scientists.

The earliest known proto-reptiles originated around 312 million years ago during the Carboniferous period, having evolved from advanced reptiliomorph terapods that became increasingly adapted to life on dry land. Some early examples include the lizard-like *Hylonomus* and *Casineria*. In addition to the living reptiles, there are many diverse groups that are now extinct, in some cases due to mass extinction events. In particular, the K–Pg extinction wiped out the pterosaurs, plesiosaurs, ornithischians, and sauropods, as well as many species of theropods (e.g. tyrannosaurids and dromaeosaurids), crocodyliforms, and squamates (e.g. mosasaurids).

Modern reptiles inhabit every continent with the exception of Antarctica. Several living subgroups are recognized:

- Testudines (turtles, terrapins and tortoises): approximately 400 species
- Sphenodontia (tuatara from New Zealand): 1 species
- Squamata (lizards, snakes, and worm lizards): over 9,600 species

- Crocodilia (crocodiles, gavials, caimans, and alligators): 25 species

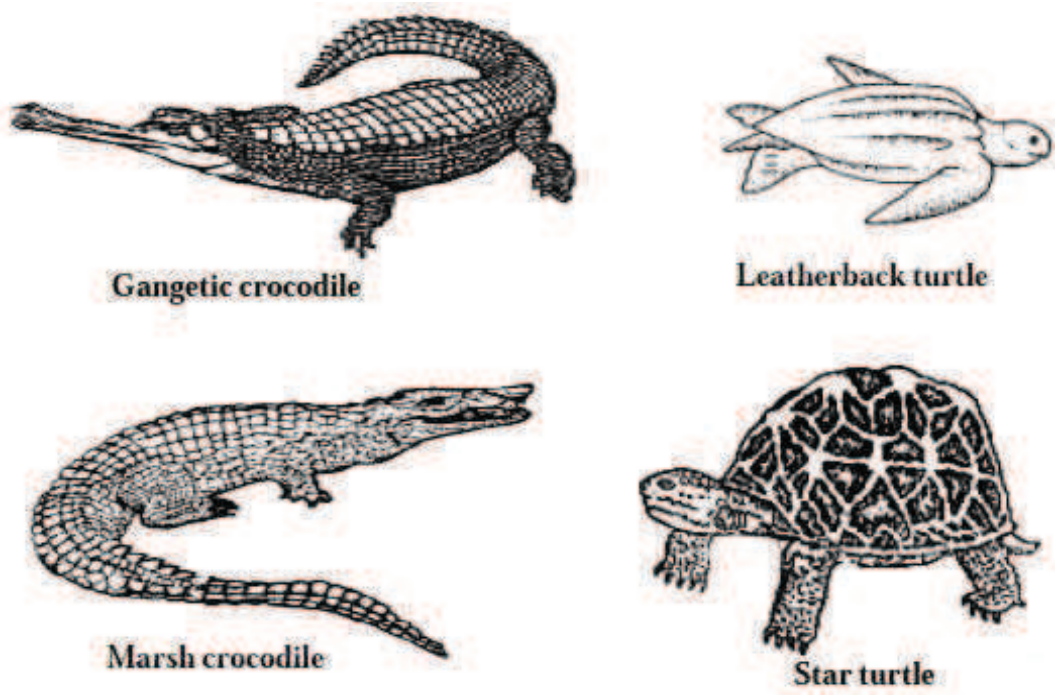

Fig.8.1 Different type of Reptiles

Because some reptiles are more closely related to birds than they are to other reptiles (crocodiles are more closely related to birds than they are to lizards), many modern scientists prefer to make Reptilia a monophyletic grouping and so also include the birds, which today contain over 10,000 species.

Reptiles are tetrapod vertebrates, creatures that either have four limbs or, like snakes, are descended from four-limbed ancestors. Unlike amphibians, reptiles do not have an aquatic larval stage. Most reptiles are oviparous, although several species of squamates are viviparous, as were some extinct aquatic clades-the fetus develops within the mother, contained in a placenta rather than an eggshell. As amniotes, reptile eggs are surrounded by membranes for protection and transport, which adapt them to reproduction on dry land. Many of the viviparous species feed their fetuses through various forms of placenta analogous to those of mammals, with some providing initial care for their hatchlings. Extant reptiles range in size from a tiny gecko, *Sphaerodactylusariasae*, which can grow up to 17 mm (0.7 in) to the saltwater crocodile, *Crocodylusporosus*, which may reach 6 m (19.7 ft) in length and weigh over 1,000 kg (2,200 lb).

8.3 GENERAL CHARACTERS

Reptiles are air-breathing vertebrate animals, a class to which lizards, crocodiles and snakes belong. It may be surprising for you to know that even the dinosaurs belong to the class reptilia. Reptiles can be easily identified with their special features like scaly integument. Class reptilia originated about 320-310 million years ago and underwent many changes to get adapted to the changing environment. Reptiles evolved from 'reptile like amphibians' and increasingly got adapted to terrestrial life. Reptiles are distributed across the planet except for Antarctica. They have higher level of intelligence as compared to birds. Some reptilian species, like the monitors, are also known to display complex behavior like cooperation. Some reptiles like snakes have toxic substances, generally termed venom, which are used as defense mechanisms and also to hunt their prey. These are fatal toxins and can even kill humans.

Morphological Characters

- The integument (skin) of reptiles is covered with epidermal scales.
- Reptiles have a large bony plate called scutes.
- Some reptiles like lizards, crocodiles, etc. have limbs whereas some species, like snakes, don't.
- Most of the reptilians have movable eye lids.

Physiological Characters

- Some species of lizards employ buccal pumping, a characteristic feature found in class amphibia. Buccal pumping is a respiratory method in which the animals move the floor of its mouth (buccal floor) in a rhythmic manner, thus allowing the respiratory gas to enter the lungs.
- Normally, oxygenated blood gets circulated all over the body and deoxygenated blood is carried back to heart. However, under specific conditions, deoxygenated blood can also be shunted to the body and oxygenated blood can be shunted back to lungs.
- Reptiles are not warm-blooded. They often depend on external sources of heat rather than regulating temperature by adjusting their metabolic rates.

- The optimum body temperature varies according to the species. However, it is typically lesser than that of warm-blooded animals, except for American desert iguana, which has a body temperature of 35–40°C, thus reaching mammalian range. The body temperature of lizards, typical reptiles, ranges from 24–35°C.
- Reptiles have low resting metabolism which helps them spend less energy to sustain life activities and thereby enables them to conserve energy.
- Reptiles are unable to produce highly concentrated urine. This is because they lack Henle's loop, a structure which is present in mammalian kidney.
- Reptiles use colon, part of their intestine, for the reabsorption of water. However, some reptiles can reabsorb water from the bladder also. They have nasal and lingual salt glands to excrete excess salt.
- Digestion is a slow process for reptiles. This is because of their lower resting metabolic rate and their inability to chew food.
- Reptiles are predominantly carnivorous, except for some herbivorous species like turtles.
- Lack of complex teeth lead to the inability to chew food and hence, some herbivorous reptiles swallow rocks and pebbles to aid churning of food.
- Most of the reptilians are adapted to see in daylight. They have a more advanced color vision than amphibians. However, in some species like the blind snake, vision is considerably reduced.
- Some snakes like pit vipers, boas and pythons have specialized visual organs (pits) that are sensitive to infrared radiations. These pits help them identify the presence of their warm-blooded prey like birds and mammals.

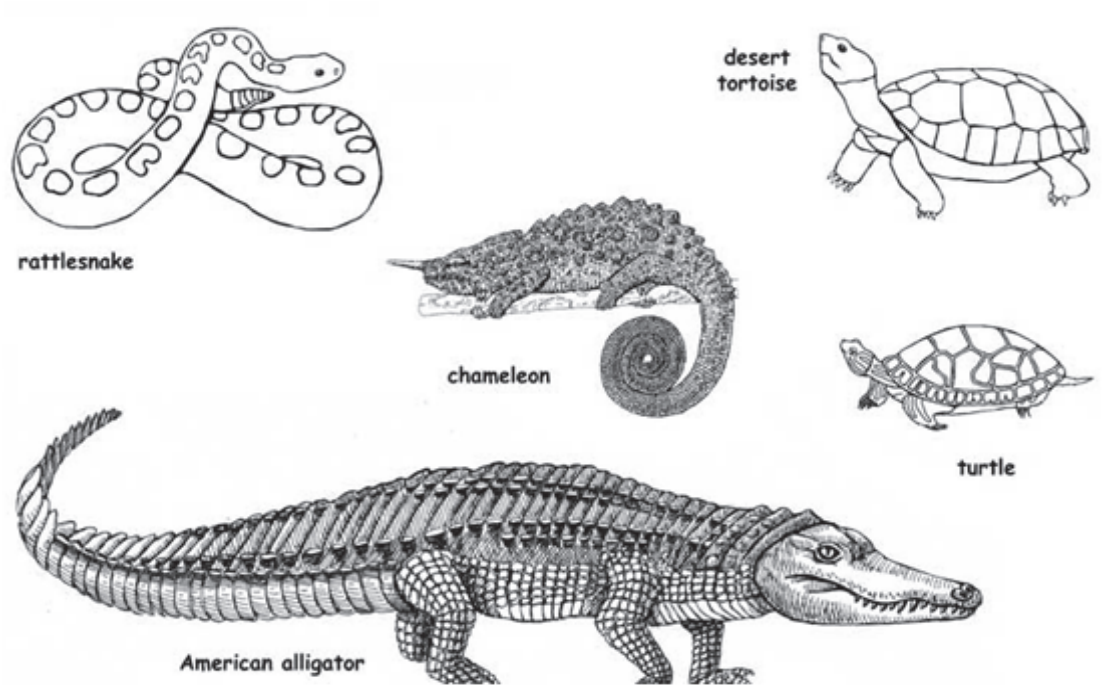

Fig.8.2 Class Reptilia

8.4 CLASSIFICATION UP TO ORDER LEVEL

Key features of Class Reptilia

- Body varied in shape, covered with horny epidermal scales, sometimes with dermal plates; integument with few glands.
- Paired limbs, usually with five toes with claws, adapted for climbing, running or paddling; limbs absent in snakes and some lizards.
- Skeleton well ossified; ribs with sternum except in snakes, forming a complete thoracic basket; skull with single occipital condyle.
- Respiration by lungs.
- Three-chambered heart, except in crocodiles which have four-chambered heart.
- Metanephric kidney; uric acid is the main nitrogenous waste.
- Ectothermic animals.

- Nervous system with primitive brain, spinal cord dominant. There are 12 pairs of cranial nerves.
- Sexes separate; fertilization internal, hemipenis as copulatory organ.
- Eggs covered with calcareous or leathery shells. Extra embryonic membranes, amnion, chorion, yolk sac and allantois are present during embryonic life.

Subclass IANAPSIDA

Anapsid reptiles are those in which the dermal bones form a complete roof over the skull, with no temporal fossae. Two main groups possess anapsid skull, the extinct **Captorhinida** and the extinct **Chelonia**.

Modern chelonians are classified into two suborders, according to the method of retracting the head into the shell. The most primitive group are the side-necked turtles (Suborder **Pleurodira**), which have very long necks to assist in catching fish. In these chelonians, the neck bends sideways in order to fit the head into the shell. Most modern species that belong to this group include the turtles, tortoises and terrapins.

Order chelonian

Tortoises and turtles do not have teeth but possess horny beaks. Tortoises are usually herbivorous while sea and fresh water turtles are omnivorous. Body is covered with a shell consisting of two parts – the dorsal **carapace** and the ventral **plastron**, which are connected by bridges between front and hind legs. The ribs and backbone are fused with the carapace.

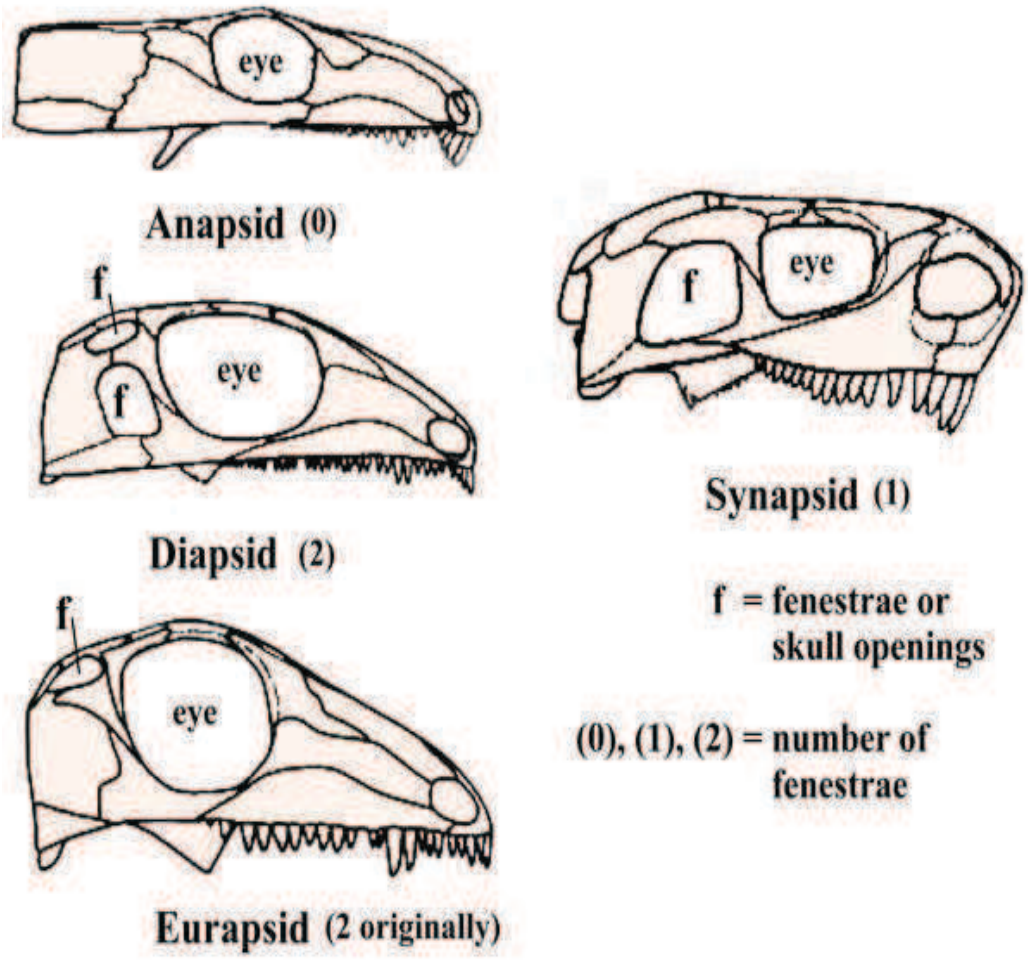

Fig.8.3 Subclass Ianapsida

Subclass II Parapsida

These are reptiles with one temporal fossa, placed high up on the skull. A number of different forms of aquatic reptile showed this form of skull, such as the Protosaurs, Nothosaurs and Placodonts but we will deal with the two largest groups – the **ichthyosaurs** and the **plesiosaurs**. These two lines of reptiles became modified for aquatic life in quite different ways but they share the same basic type of skull organisation, with minor differences. Both **Ichthyosaurus** and the **Plesiosaurus** became extinct at the end of the Cretaceous when many other terrestrial reptiles including dinosaurs died out.

Subclass III Diapsida

These reptiles possess two temporal fossae in the skull and they have been the most successful and diverse of all the reptiles. They include the dinosaurs and pterosaurs which dominated the land and air during the Mesozoic era and also include the most successful of modern reptiles, such as the crocodiles, snakes and lizards.

The diapsid reptiles are divided into two major goups, the **Archosauria** and the **Lepidosauria**, which share the same type of temporal vacuities in the skull, but there are a number of differences in their skull construction which makes it possible that they may have evolved independently from separate cotylosaur ancestors.

Order Rhyncocephalia

The order contains only two species that live on some islands off the coast of New Zealand.They look like lizards but there are differences that set the tuatara apart from lizards. The tuatara spends daytimes in burrows. It comes out in the evening to feed on insects and other invertebrates.

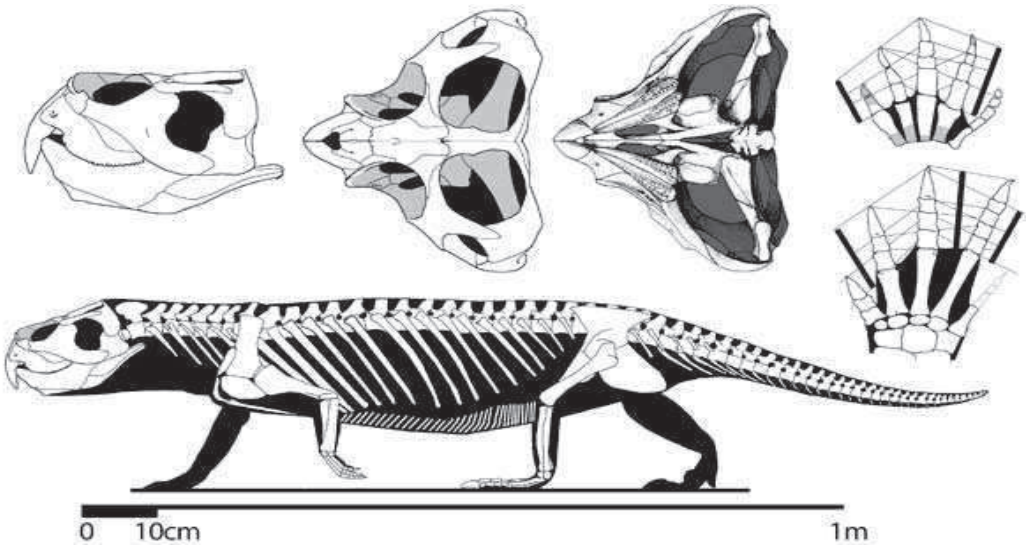

Fig 8.4 *Order Rhyncocephalia*

Order Squamata

The order includes Lizards and snakes, which are creepers and inhabit a variety of habitats. Snakes are carnivorous but lizards eat a variety of foods including plants and insects. Snakes have descended from lizards and there are many similarities between them. Some characteristics that distinguish snakes from lizards are:

- Snakes do not have eyelids but lizards have.
- Snakes usually have one row of scales on the belly; lizards have many.
- Snakes do not have legs; most lizards have legs.
- Snakes have jaw bones that disarticulate allowing them to swallow large objects. Lizard jaw bones do not disarticulate.

Order Crocodilia:

This order includes alligators, caimans, crocodiles and gharials that are found in and near water in warmer areas of the world. They eat fish, birds, turtles, and mammals. Members of the crocodile group have legs and feet designed for walking on land and a strong flattened tail used for swimming. The three groups are distinguished from one another by the shape of their heads. Alligators have a broad, rounded snout; while the crocodiles have a triangular head with a more pointed snout and gharials have a very long and narrow snout.

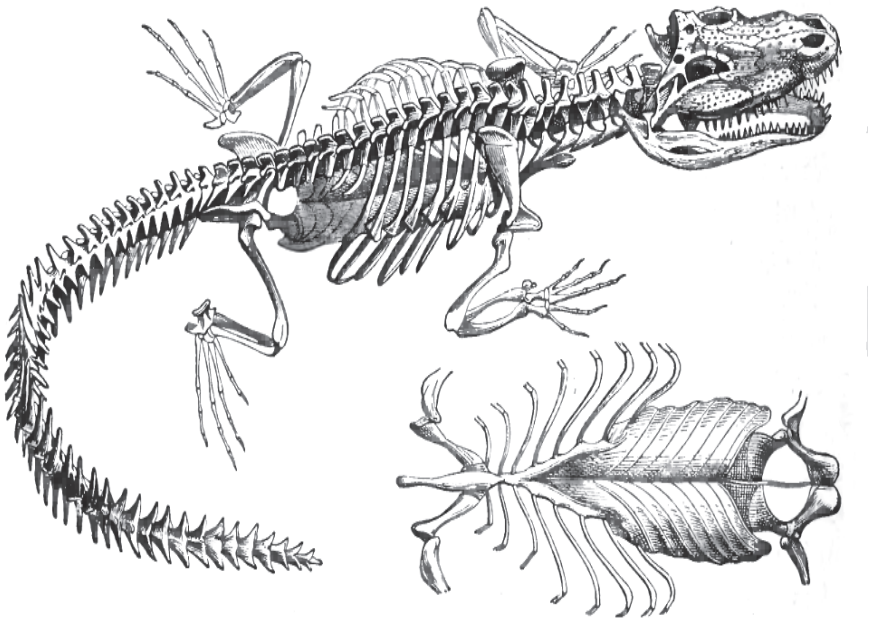

Fig 8.5 Crocodilia

The Dinosaurs:

Dinosaurs belonged to three orders:

- **Order Saurischia -** They possessed lizard-like pelvic girdle in which ischium and pubis bones diverge from the base. These dinosaurs were both bipedal and quadrupeds, carnivores as well as herbivores. Examples are, *Allosaurus, Tyrannosaurus, Brontosaurus, Diplodocus, Brachiosaurus* and *Struthiomimus*.

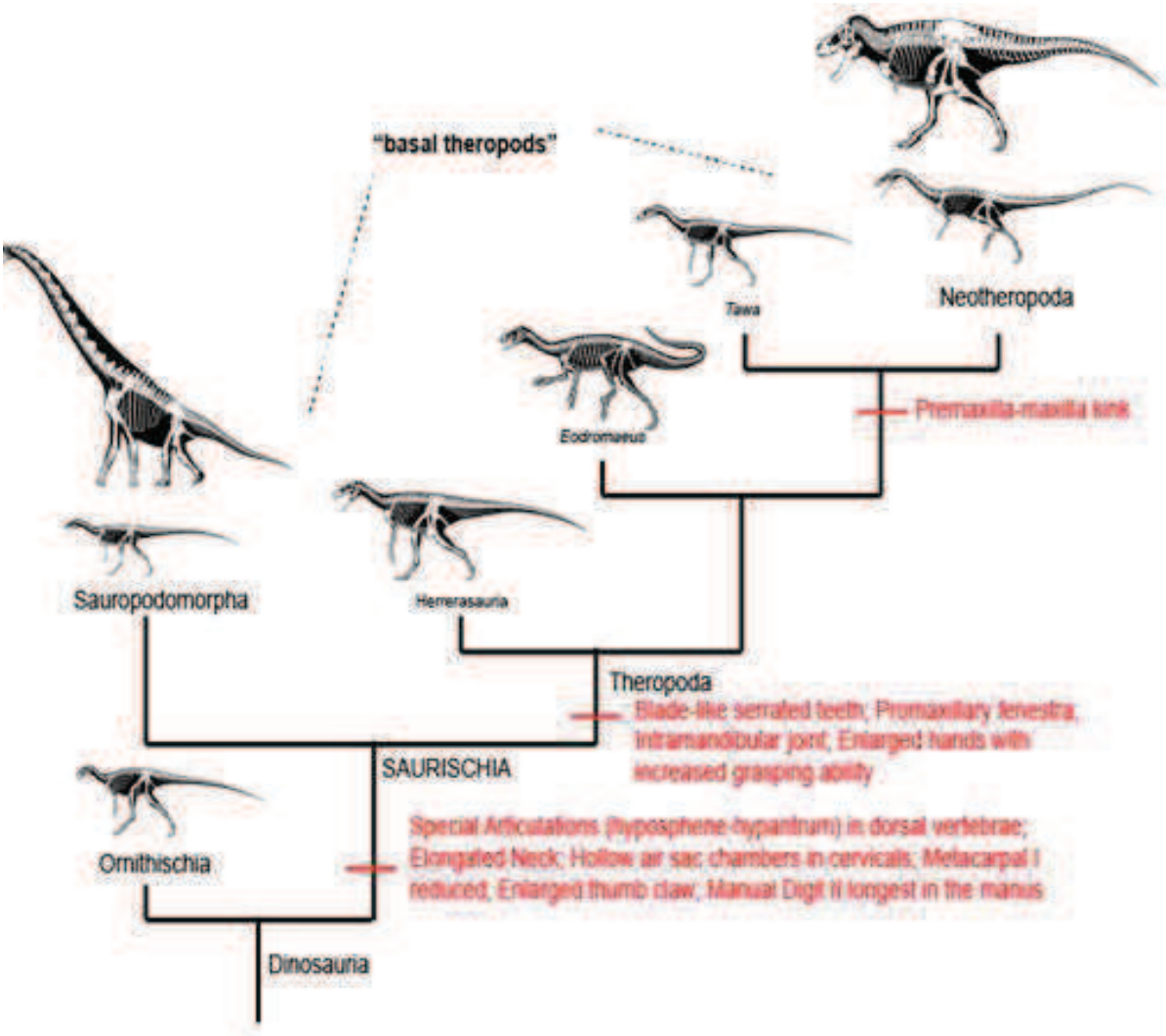

Fig 8.6 Order Saurischia

➢ **Order Ornithischia** - They were dinosaurs with bird-like pelvic girdle in which both ischium and pubis are directed backwards. Examples include *Iguanodon, Stegosaurus, Triceratops, Camptosaurus* and *Ankylosaurus.*

➢ **Order Pterosauria** - They were flying reptiles in which forelimbs were modified to support a patagium that stretched from forelimbs to hind limbs. Their size varied from that of sparrow to giants that had wing span of 12 metres.

➢ **Subclass IV Synapsida** - These reptiles have one temporal fossa, on the lower side of the remporal region of the skull. They were the most successful and dominant reptiles during the Permian period. In the Mesozoic era they were largely replaced by other lines of reptiles such as dinosaurs, but the surviving synapsids gave rise to the mammals. There is a range of fossil species of these reptiles throughout the Mesozoic. At the start of the era they show typically reptilian characteristics but by the end of the era they became so mammal-like that it is difficult to know whether they should be classified as mammals or reptiles.

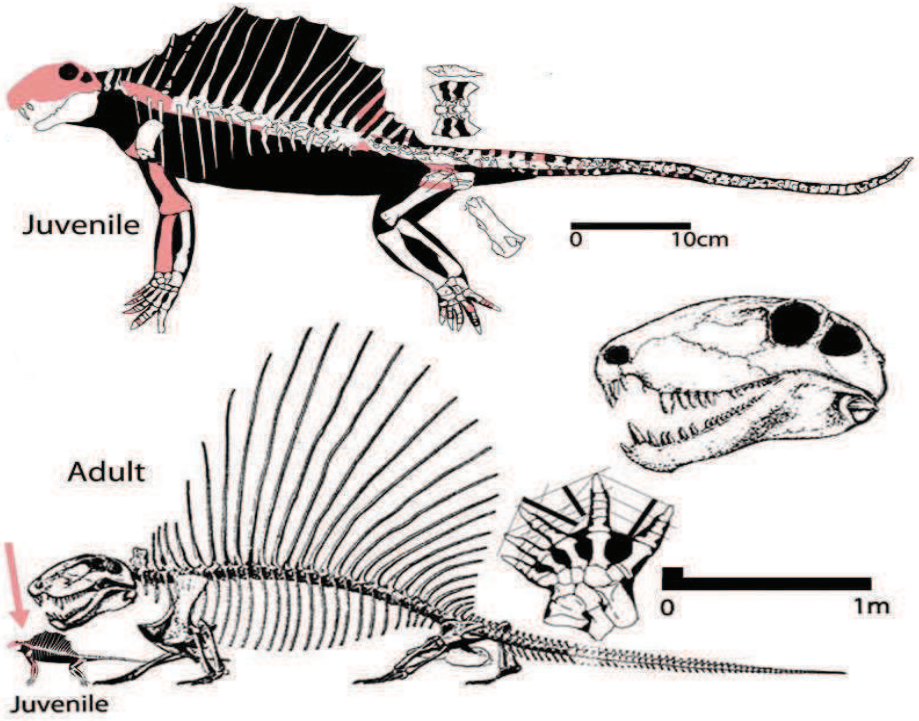

Fig 8.7 Animal of the subclass Synapsida

8.5 EXTINCT REPTILES

The most famous members of the reptile family, the dinosaurs, became extinct as a result of the impact of a huge meteor, which changed the Earth's environments, and as a result, many species could not survive. In the last few centuries however almost all known reptile extinctions can be attributed to human activity – either directly, through overhunting, or indirectly, by introducing predatory species, or altering the habitat the reptiles rely on for survival. Mariner's often relied on reptiles (particularly tortoises) on strategic islands as a source of food, and in the nineteenth century in particular severely depleted some populations of reptiles, and completely wiped out others. Once we lose them, we will never get them back.

Below is a list of recorded extinctions of reptile species, with their locality, date of last sighting, and the reason for their disappearance. Human activity has been responsible in all known cases. There is also the Black Soft-shell Turtle (*Aspideretes nigricans*), which is extinct in the wild but can be found in a single artificial temple pond in Bangladesh.

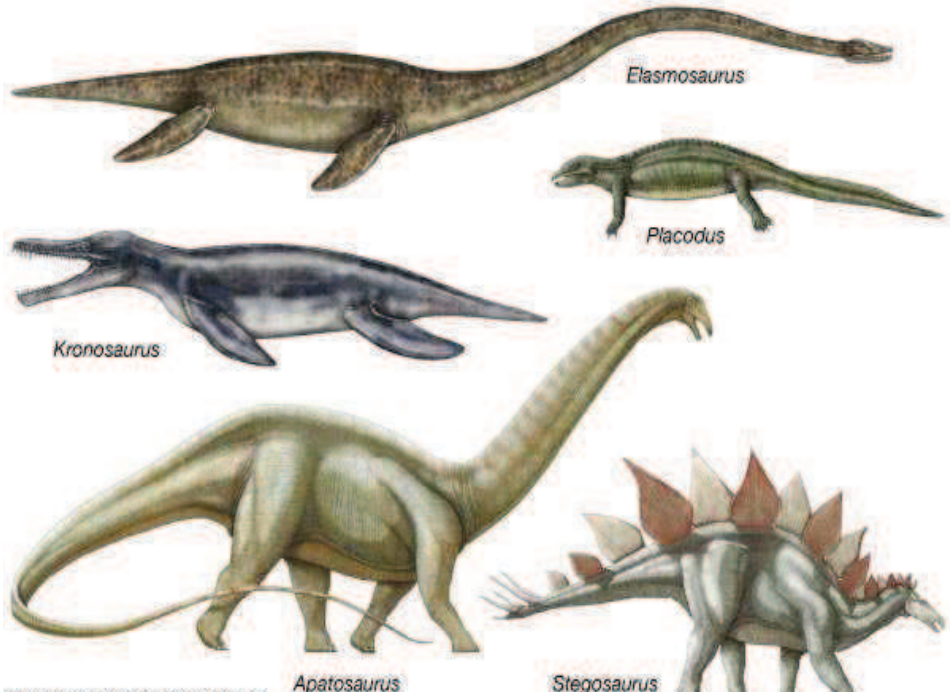

Fig.8.8 Some of the Extinct Reptiles

8.6 GENERAL STUDY OF UROMASTYX

Uromastyx is a genus of African and Asian agamidlizards, the member species of which are commonly called spiny-tailed lizards, uromastyces, mastigures, or dabb lizards. Lizards in the genus Uromastyx are primarily herbivorous, but occasionally eat insects, especially young lizards. They spend most of their waking hours basking in the sun, hiding in underground chambers at daytime or when danger appears. They tend to establish themselves in hilly, rocky areas with good shelter and accessible vegetation.

Taxonomy:

The generic name (*Uromastyx*) is derived from the Ancient Greek words *ourá* (οὐρά) meaning "tail" and *mastix* (meaning "whip" or "scourge", after the thick-spiked tail characteristic of all *Uromastyx* species.

Species:

The following species are in the genus *Uromastyx*. Three additional species were formerly placed in this genus, but have been moved to their own genus, *Saara*.

Fig.8.9Uromastyx

Description:

The size ranges from 25 cm (10 in) (*U. macfadyeni*) to 91 cm (36 in) or more (*U. aegyptia*). Hatchlings or neonates are usually no more than 7–10 cm (3–4 in) in length.Like many reptiles, these lizards' colors change according to the temperature; during cool weather they appear dull and dark but the colors become lighter in warm weather, especially when basking; the darker pigmentation allows their skin to absorb sunlight more effectively.

Their spiked tail is muscular and heavy, and can be swung at an attacker with great velocity, usually accompanied by hissing and an open-mouthed display of (small) teeth.Uromastyxs generally sleep in their burrows with their tails closest to the opening, in order to thwart intruders.

Fig.8.10 Uromastyx macfadyeni

Distribution:

Uromastyx inhabit a range stretching through most of North and Northeast Africa, the Middle East, ranging as far east as Iran. Species found further east are now placed in the genus *Saara*.*Uromastyx*occur at elevations from sea level to well over 900 m (3,000 ft). They are regularly eaten, and sold in produce markets, by local peoples. *Uromastyx* tend to bask in areas with surface temperatures of over 50 °C (120 °F)

Reproduction –

A female *Uromastyx* can lay anywhere from 5 to 40 eggs, depending on age and species. Eggs are laid approximately 30 days following copulation with an incubation time of 70–80 days. The neonates weigh 4–6 g (0.14–0.21 oz) and are about 5 cm (2 in) snout to vent length. They rapidly gain weight during the first few weeks following hatching. A field study in Algeria concluded that Moroccan spiny-tailed lizards add approximately 5 cm (2 in) of total growth each year until around the age of 8–9 years. Wild female uromastyx are smaller and less colorful than males. For example, *U. (dispar) maliensis* females are often light tan with black dorsal spots, while males are mostly bright yellow with mottled black markings. Females also tend to have shorter claws. In captivity female *U. (dispar) maliensis* tend to mimic males in color.Maliensis are, therefore, reputably difficult to breed in captivity.

Diet-

These lizards acquire most of the water they need from the vegetation they ingest.Giving a Uromastyx a water bowl can lead to higher humidity in the cage and can cause problems for the animal.

Captivity –

Egyptian spiny-tailed lizard (*Uromastyxa egyptia***)**

Historically, captive *Uromastyx* had a poor survival rate, due to a lack of understanding of their dietary and environmental needs. In recent years, knowledge has significantly increased and appropriate diet and care has led to survival rates and longevity approaching and perhaps surpassing those in the wild.

The Mali Uromastyx (*Uromastyx (dispar) maliensis*) is considered an ideal species to choose as a pet because they readily adapt to a captive environment. Another species of *Uromastyx* that adapts to captivity well, and comes in "red" and "yellow", is *Uromastyxgeyri*, commonly called the Saharan Uromastyx. The red version is marketed as a red Niger Uromastyx but the yellow version is marketed as a yellow Niger Uromastyx. Proper enclosures can be costly, as these are roaming animals with large

space needs for their size, combined with the need to provide heat and ultraviolet light. Though the lizards bask at very high temperatures, there must be a temperature gradient within the enclosure allowing them to cool off away from the heat lamps. A cooling-down period over winter months can trigger the breeding response when temperatures rise in the spring. The temporary slowing-down of their metabolisms also lengthens the animals' lifespans.

Fig 8.11 *Egyptian spiny-tailed lizard (Uromastyxa egyptia)*

Uromastyx are burrowing lizards, and need substrate deep enough to burrow in, or a low structure under which to hide. In the wild, these lizards' burrows can reach 3 m (10 ft) in length.

Nutrition -

Captive uromastyxs' diets should be largely herbivorous, consisting primarily of endive, dandelion greens, bokchoy, escarole, and most ground growing vegetables with little to no sugar, or of course an appropriate type of store-bought vegetarian lizard food. Some lettuces have almost no nutritive value. The lighter, whiter lettuce is not as nutritionally effective as the darker green lettuce. It is very important to avoid spinach, chard and flowering kale in the diets of all reptiles,. The lizards' food can be dusted with

calcium and a uromastyx designed supplement to help prevent health problems. While young uromastix, like young iguanas, do eat some insects in order to gain access to the added nutrients while they are rapidly growing, the high levels of protein may cause liver damage in adults. These animals are primarily herbivores, as stated above, and so it's generally felt that they should only be fed plant matter. In the wild, adult Malis have been reported to eat insects at certain times of the year, when it is hot and their only food source available would be insects.

8.7 POISONOUS AND NON POISONOUS SNAKES

8.7.1 IDENTIFICATION OF POISONOUS SNAKES

Most of the snakes are non-poisonous. **Identification of poisonous or non-poisonous snakes** is important because sometimes the bite of a non-poisonous snake may lead to `death out of fear. The poisonous snakes possess certain characteristics by which it is possible to distinguish them from non-poisonous snakes.

The poisonous snakes are identified by a careful examination of the following points.

I. Nature of the Tail -The tail of a snake should be observed first. If the tail of a snake is flat, laterally compressed and oar-shaped (adaptation to swimming in water), it is a sea snake. All sea snakes are poisonous. The body is covered by small scales dorsally. Ex: Hydrophis, Enhydrina. If the tail ends bluntly, it is non-poisonous. If the tail is round orcylindrical and pointed, it may be poisonous or non-poisonous. It may be terrestrial or fresh water.

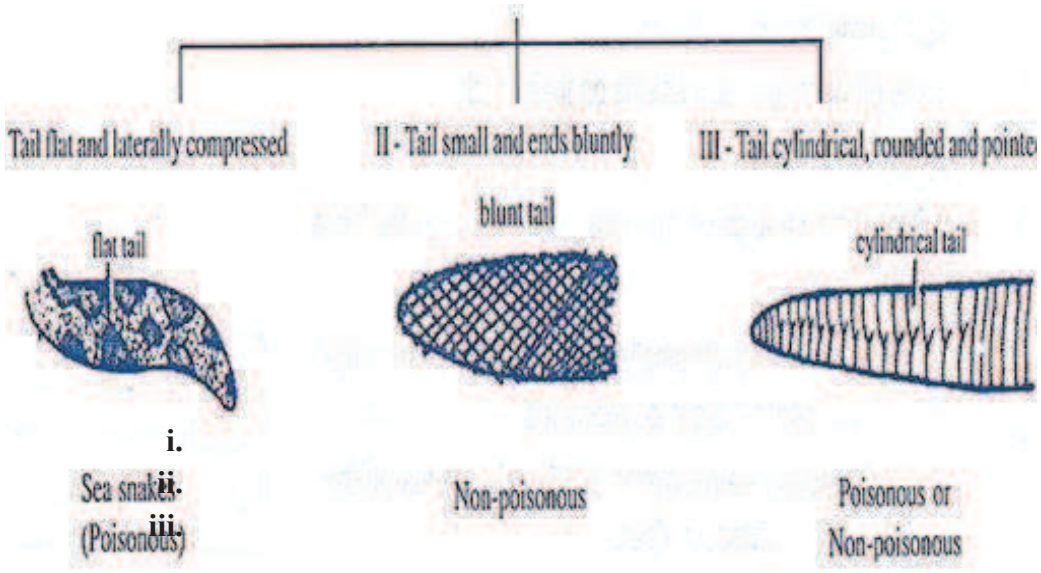

Fig 8.12 Identification of Poisonous & Non Poisonous snake (Nature of tail)

II:Nature of The Ventrals-

If the tail is round and not compressed, then examine the ventrals (scales on the ventral side of the trunk).

- If the ventrals are small and narrow, it is a non-poisonous snake.
- In some non-poisonous snakes like Python, the ventrals are fairly broaa, but do not extend compieiely across the belly. On either side of ventrals, small scales are present.If the ventrals are broad extending completely across the belly, it may be poisonous or a non-poisonous snake.

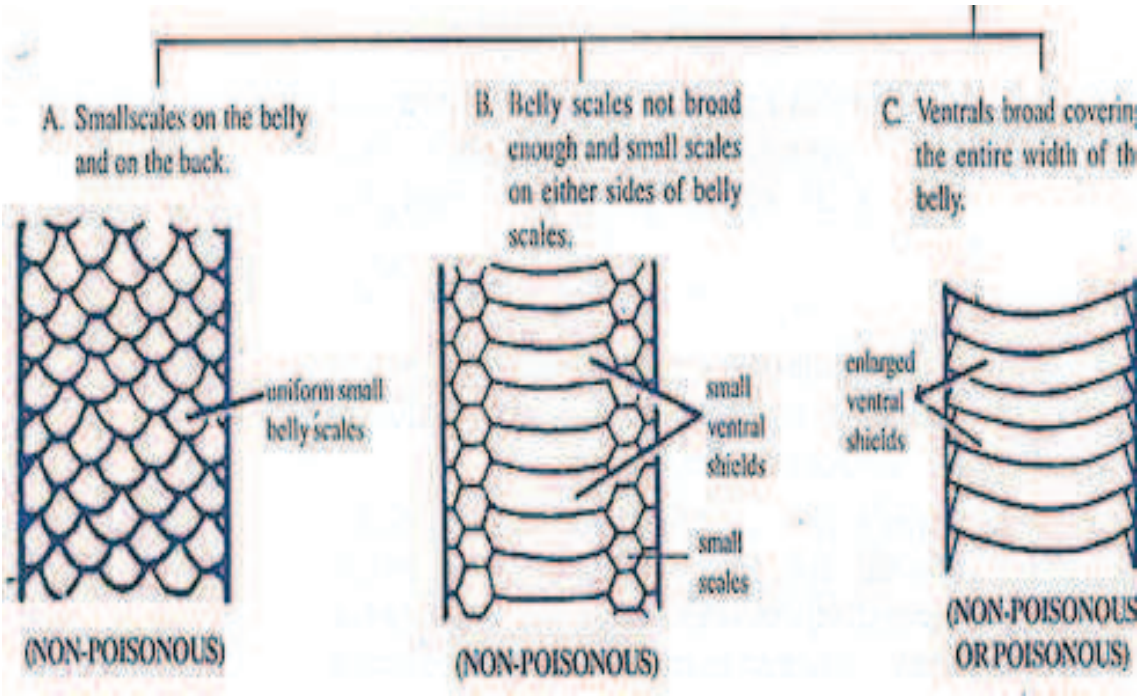

Fig. 8.13 Identification of Poisonous & Non Poisonous snake (Nature of ventral)

iv: Nature of the Scales On The Head :-

If the tail is round and the ventrals are broad, then examine the head of the snake.

- If the head is triangular and covered with small scales and not with shields, it is a **viper.** All vipers are poisonous. Vipers are of two [L] types. ***1. Pit vipers, 2. Pitless vipers.***
- If there is a loreal pit between the eye and nostril, the snake is a pit viper (pit organ is a***thermoreceptor)***
- ***Eg: Trimeresurus (lachesis)***
- Some pit vipers possess shields on their heads. ***Eg :Ancistrodon***
- If there is no loreal pit between the eye and the nostril, it is a pitless viper

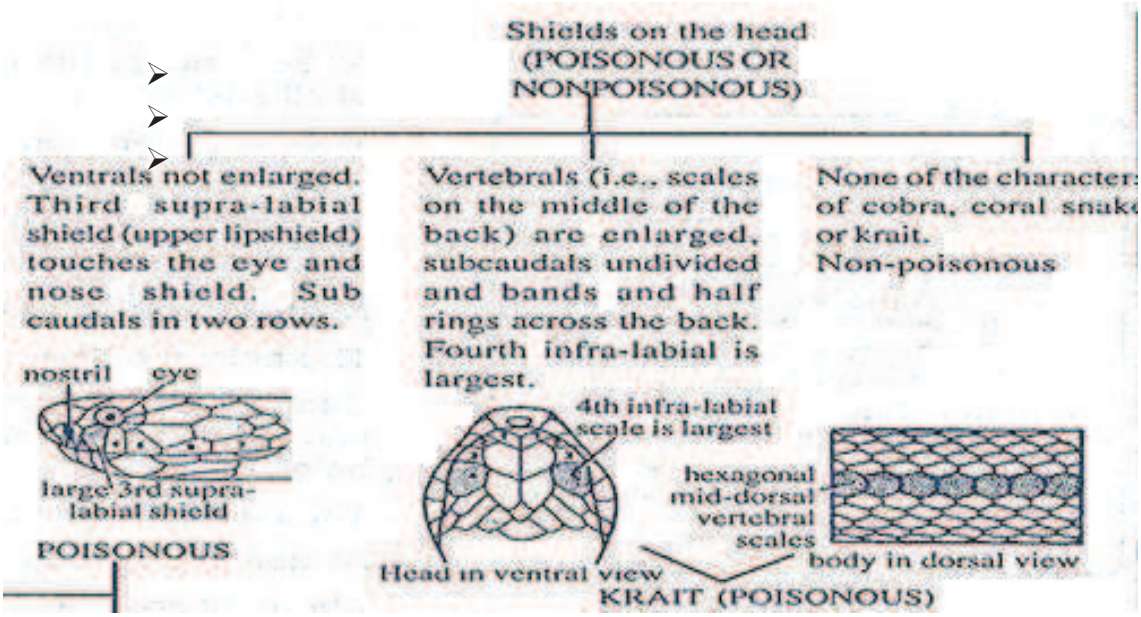

Fig 8.14 Identification of Poisonous & Non Poisonous snake (Nature of scale on the head)

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- If the head is covered with small scales and there is no loreal pit, then the sub-caudals are to be examined.
- If sub-caudals are in two rows and there is no loreal pit, then the snake is ***Russels viper.***
- It is a pitiess viper with aiarge body and bears 3 rows of large diamond-shaped spots on the dorsal side of the body.
- If the sub caudals are in a single row and there is no ioreai pit, then the snake is ***Echiscarinata***(the little Indian viper). The head bears arrow shaped mark on the head. It is ***phoorsa***

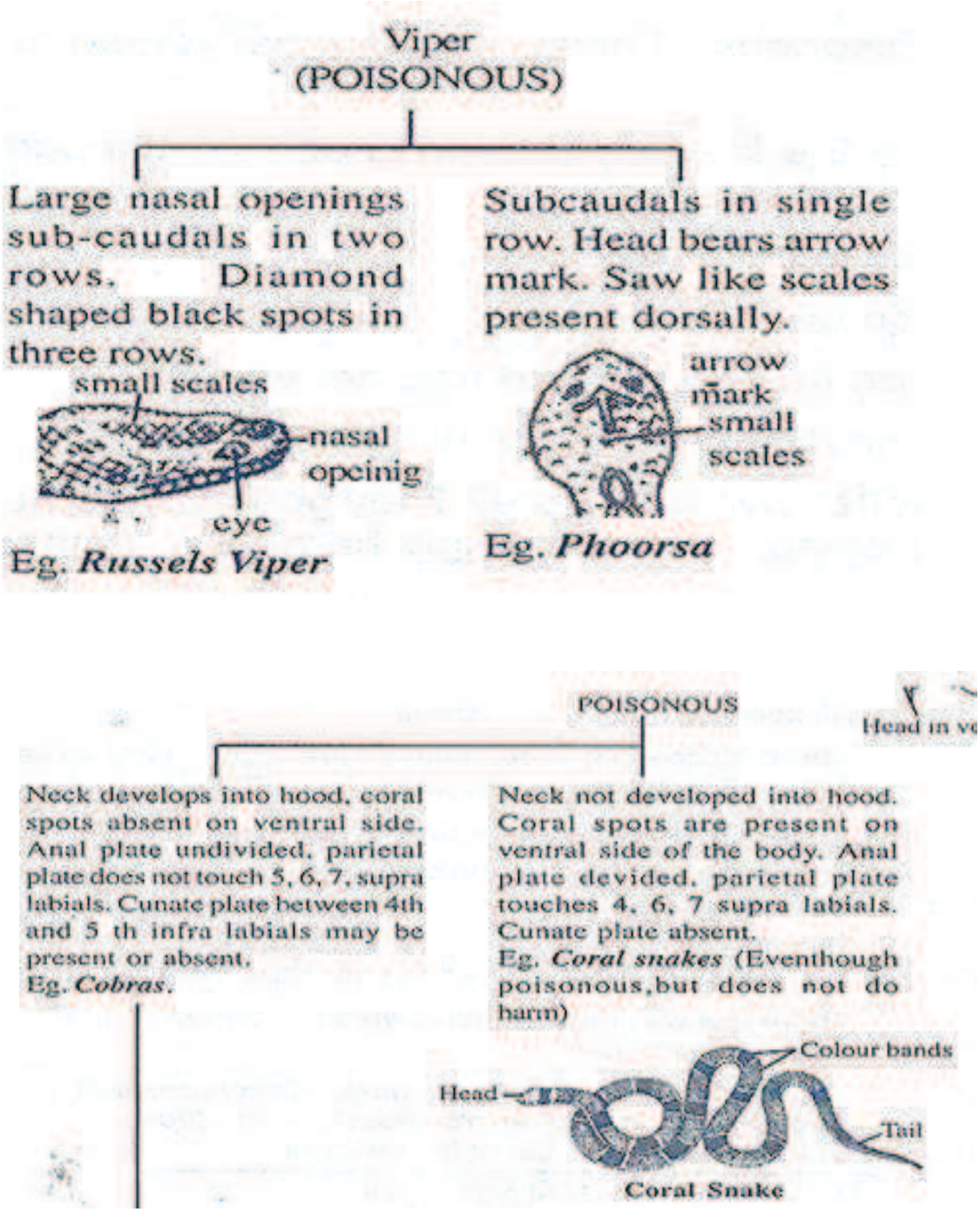
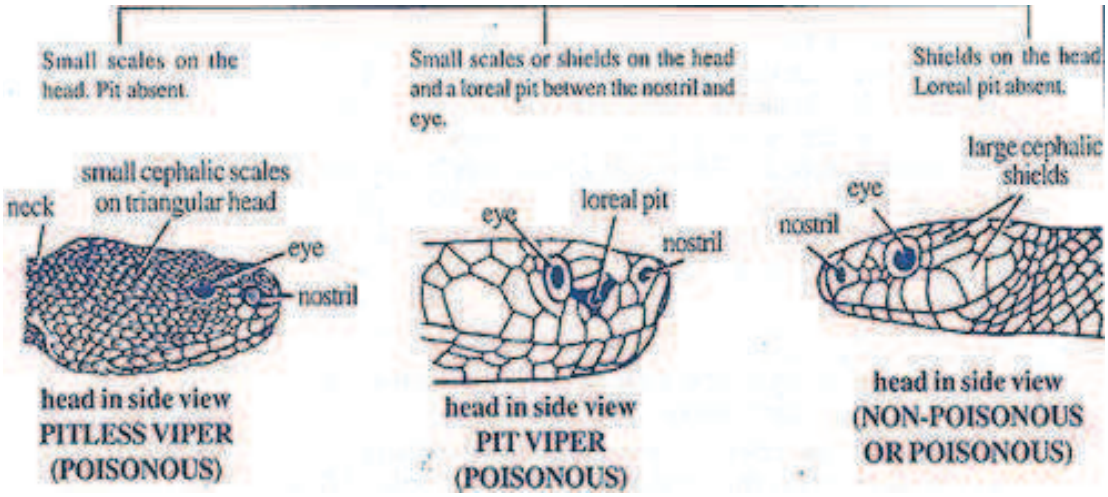


Fig 8.15 Scale on body

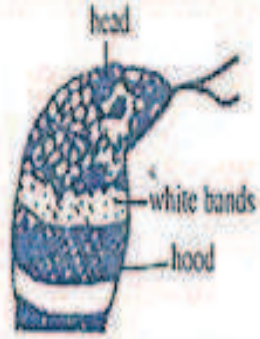
v. From the Nature of the Vertebrals -

- If the head is covered with **shields,** not with small scales it may be poisonous or non poisonous. Then examine the ***vertebrals*** (scales present along the mid-dorsal line on the back).
- If the vertebrals are large and hexagonal, it is a **krait** and it is highly poisonous. In addition to the enlarged vertebrals, the krait is characterized by the presence of only **4 infra-labials** of which the fourth one is the largest (infra-labials are the shields forming the margin of the lower jaw). The sub-caudals are present in a single row in krait. **Eg; Bungarus.**
- If the vertebrals are not large, then examine the ***supra-labial shields*** (the shields forming the margin of the upper jaw). If the third **supra-labial shield** touches the nasal shield and the eye, it is either a cobra or a coral snake. Both cobras and coral snakes are poisonous.

Cobras ***(Naja naja, Naja hanna)*** are identified by a hood and the coral snakes ***(C allophis, Hemibungarus)*** are identified by the presence of brilliantly coloured peculiar spots on the belly and by the absence of hood.



Body bears white or yellow bands. Sub-caudals in single row nearer to cloaca but in two rows at the top of the tail. Hood bears bands. Cunate plate between 4th and 5th infralabials is absent. Largest poisonous snake.



Eg. *King Cobra.*

Sub caudals in two rows continuously. Hood bears spectacle mark or oval shaped mark. Cunal plate present beteen 4th and 5th infralabials. Small common cobra.

Eg. *Naja naja*

Fig 8.16 Snake Bite

Vi: From the Nature of Snake Bite:

Depending on the nature of bite, it can be judged whether it is a poisonous or non-poisonous snake.

When a poisonous snake bites, there will be 1 or 2 punctures on the skin of the victim (the punctures are made by fangs). If a non-poisonous snake bites, many punctures are usually made on the skin by the maxillary teeth of upper jaw.

8.7.2 IDENTIFICATION OF NON-POISONOUS SNAKES

- **Non-Venomous Snakes :**

There are no universal distinguishing features that separate venomous from non-venomous snakes. People must learn to identify the dangerous species of snakes in their areas or the areas they plan on visiting.

Non-venomous snakes have teeth, just like the venomous variety. So even in the case of a bite from a non-venomous snake, care should be given to watch for infections, as with any small injury. Bites from large non-venomous snakes can also be devastating - some large python and boas are able to cause massive lacerations requiring urgent medical care.

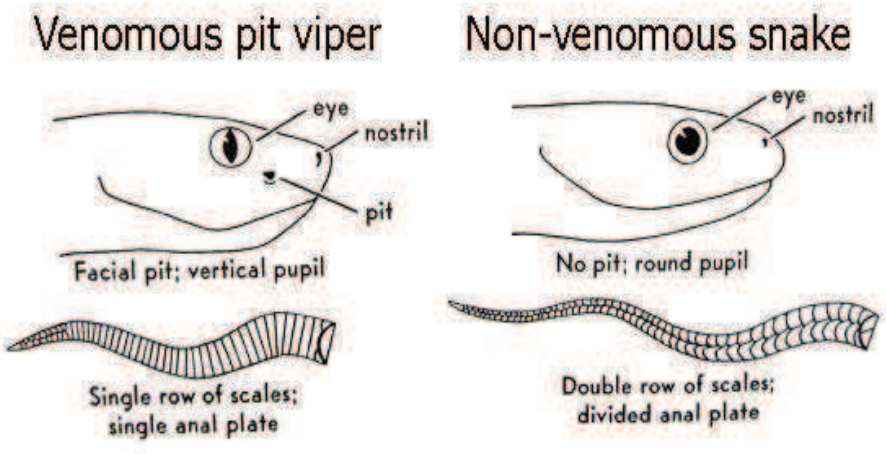


Fig 8.17 Venomous pit viper v/s non venomous snake

- **Advice :**

It's best to leave all snakes alone, just like any wildlife. They have their place in nature and would certainly prefer to leave us alone as well.

- **How They Kill**

Many non-venomous snakes constrict their prey. Constriction is not a bone breaking experience like we often see in the movies. A snake will strike out to bite its prey, throw a couple of coils around it and begin to squeeze. Two things generally happen: every time the animal (prey) exhales, the snake will squeeze tighter. Eventually, the animal will not be able to inhale.

However, there is so much power behind the coils that most animals typically die from heart failure because so much pressure is being applied to the chest cavity that the heart doesn't have any room to continue beating. Death is very rapid, and in most cases takes less than a minute.

- **Defenses**

All snakes possess teeth that can be used in defensive bites. Most snakes rely on camouflage to avoid being seen, others coil up in a tight ball with the head in the middle, some rattle the tail, and a few rub their scales together to produce a rasping "leave me alone" sound, but almost all will flee if given even the slightest opportunity.

Non-Venomous Snakes:

Most of the world's snakes are what are referred to as clinically non-venomous. This means they do not produce a toxin that is clinically significant to people. However, many harmless-to-humans snakes, like Hognose snakes, Garter snakes and Rat snakes for example, do produce toxins that are scientifically or technically venomous.

Boas, pythons, bull snakes and king snakes are examples of truly non-venomous snake species.

BITING MECHANISM OF SNAKES:

The mechanism of biting is a complicated process and it can be described in the following three steps.

(a) Opening of the mouth:

By the contraction of digastric muscles the mouth is opened.

(b) Rotation of maxilla:

As the mouth opens the lower jaw moves forward and a rotation of the squamosal, quadrate and mandible in relation to each other occurs. Now the sphenoptery goid muscles contract. This contraction results in the forward movement of ptery goid and up-pushing of the ectoptery goid. The upward movement of the ectopterygoid brings about a rotation of maxilla on its own axis round the lacrymal and as a result the fang is raised and becomes directed forward. The fang is nearly horizontal in position when the mouth remains closed. But during opening of the mouth to bite, the fang assumes almost vertical position.

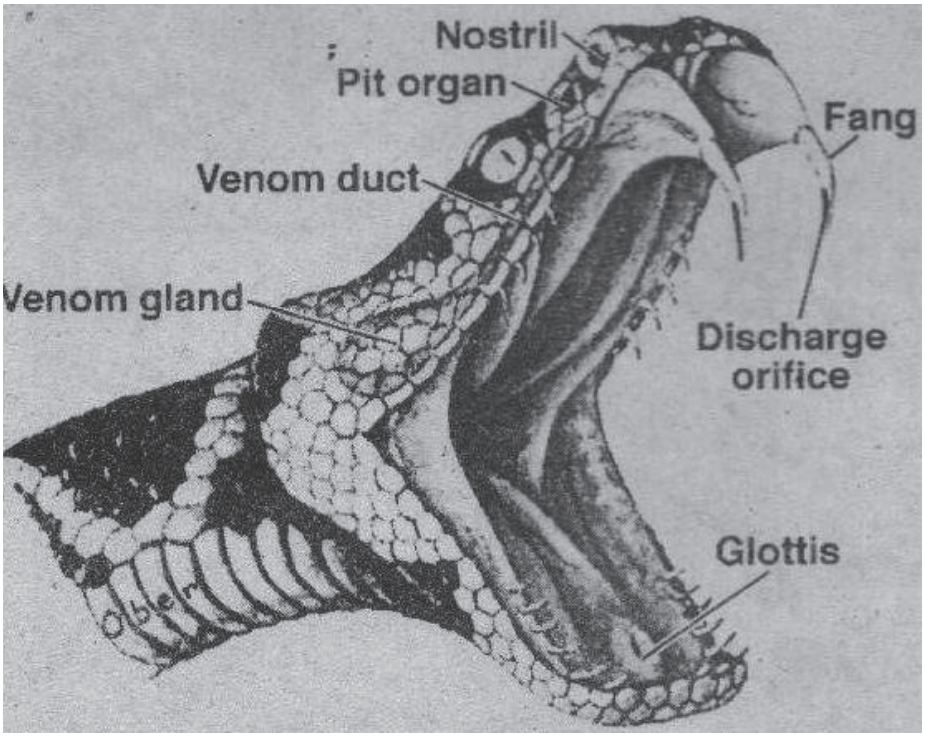


Fig 8.18 Biting apparatus in snake

(c) Closing of mouth:

The closing of the mouth is brought about by the contraction of the temporalis and sphenopterygoid muscles. The point of fang is directed back ward while the mouth is closed. It takes longer time to open the mouth than to close it.

(d) Toxicity of Snake Bite

The snake poison or snake venom is useful in killing the prey and in defense.

The poison is a pale yellow colored fluid made up of a mixture of two major types of powerful enzymes. They are

Neurotoxin:

It affects the central nervous system; especially the motor nerves and causes cardiac and respiratory failure. It is present in the poison of cobra (cobradin), Kraits, sea snakes etc. (except vipers).

Haemotoxin:

It includes **cardio toxins and Haemorrhagins.** It is present in the poison of vipers (viperidin).

- **Cardiotoxins:** Affects the heart'
- **Haemorrhagins:** It affects cardiovascular system. They contain enzymes like proteolysins, lecithinases, phosphoridases etc. **Proteolysins**and **Lecithinases**destroy the endothelium of blood vessels and cause profuse bleeding.
- **Phosphoridases**produce haemolysis leading to cardiac and
- Circulatory failures.

i. Blood clotting results in thrombosis

ii. Cardiac and respiratory failures

iii. Clotting power of the blood is reduced, which results in profuse bleeding.

iv. Blood corpuscles, linings of the blood – vessels and other tissues are destroyed.

v. Due to the presence of **hyaluronidase**in the venom there is a rapid spreading of venom.

Treatment of Snake Bite:-

First of all it must be confirmed whether the snake, which had bitten man, was in fact poisonous. A person bitten by any type of snake should by psychologically treated as it has been reported that, sometimes, due to the fear only the heart – failure results and man dies, even though bitten by a non-poisonous snake.

If a man is bitten by a poisonous snake the following first aid and treatment are prescribed:

(i) Immediately send for a doctor and do not disturb the patient.

(ii) Undue excitement and exertion should be avoided.

(iii) If bitten on a limb, a tourniquet should be applied between the wound and the heart. This constriction should be either of rubber tubing or of handkerchief etc. The constrictions should be kept only for 20 minutes and then release J for one minute until the skin becomes pink and is again tigmened.

(iv) After applying the constriction, make an incision about 2 cm. deep into the bitten area and keep ice on it. Suction of the venom may be done by a suction cup and **not by mouth.**

(v) Do not apply potassium permanganate to the wound, as it is a tissue poison. Very recently, its use has been objected to.

(vi) Keep the patient warm and absolutely at rest.

(vii) Alcoholic beverages should never be given.

(viii) Give hot coffee, tea or milk, if possible.

8.8 SUMMARY

Most small children can tell you that ‘reptiles’ are the snakes, lizards, crocodiles, and turtles (perhaps with the dinosaurs thrown in) — suggesting that it’s easy to tell the difference between reptiles and other animals. Unfortunately, evolutionary biologists struggle with the same task, because phylogenetic analysis tells us loud and clear that these different types of what we loosely call ‘reptiles’ are not particularly closely related to each other (Figure 1). On the evolutionary tree, some of them (dinosaurs, crocodiles) are much more closely related to birds than to the other animals that we call reptiles. Other reptiles are the descendants of very ancient lineages; for example, turtles separated from the other reptiles, including the now-dominant Squamata (lizards and snakes), at least 200 million years ago. And

another 200-million-year-old lineage has left just a single survivor, a lizard-like creature (the tuatara), on a few islands in New Zealand.

8.8 GLOSSARY

Aestivate	The behavior of laying dormant in the Summer to avoid heat or drought
Albinism	A genetic condition that manifests as a lack of pigment
Allochthonus	Not native
Amelanistic	Lacking in dark pigment
Anerythristic	Lacking in red pigment
Antivenin	The medicinal treatment for envenomation
Basking	Laying in the direct rays of the sun for thermoregulatory or theraputic reasons
Binomial	A scientific name consisting of two parts, a genus and a species
Biota	The living organisms in a given area
Carapace	The dorsal portion of a turtle shell
Carnivorous	Meat eating
Chelonian	A turtle or tortoise
Cloaca	The common cavity and orofice where digestive, urinary and reproductive products are passed.
Colubrid	Snakes belonging to the taxonomic family Colubridae.
Crepuscular	Describes the behavior of being active during twighlight hours(dusk or dawn)
Crocodilian	A corcodile, alligator, caiman, or gahrial.
Crotalin	Snakes belonging to the taxonomic family Viperidae, but of the sub-family Crotalinae. These are the pit-vipers.
Cryptic	Describes the behavior of remaining hidden
Cytotoxin	A chemical toxin that acts directly on the body tissue. It is the most physically destructive component of snake venom.

8.9 SELF-ASSESSMENT QUESTION

Multiple choice questions:

1. Lateral undulation is used by snakes in:
   (a) Serpentine locomotion
   (b) Forword locomotion
   (c) Locomotion in burrows
   (d) Locomotion in sand

2. The poison glands of snake are really _____
   a) Labial glands
   b) Tear glands
   c) Salivery glands
   d) Sebaceous glands.

3. A flying lizard is _____
   a) Chameleon
   b) Draco
   c) Neurotoxic
   d) None of these.

4. The Venom of snake is _____
   a) Haemolytic
   b) Neurotoxic & Homotoxic.
   c) Neurotoxic.
   d) None of these.

5. The study of reptiles is known as:
   (a) Herpetology
   (b) Ornithology
   (c) Icthyology
   (d) Osteology

6. In case of snake bite the best medicine to inject is _____
   a) Antivein
   b) Penicillin.
   c) Antibiotics
   d) Streptomycin.

7. Which is not true for COBRA?
   (a) A= Altered
   (b) CO= Spinal cord
   (c) BRA =Brain
   (d) COB= Coagulation of blood

Answers

1(a) 2 (a) 3 (b) 4 (b) 5 (a) 6 (a) 7 (a)

8.10 TERMINAL QUESTIONS/ANSWER

Q 1 - Give the classification of reptilia?

Q 2 - Give the general characters of the reptilia?

Q 3- Describe the Biting Mechanism of snakes?

Q4 - Classify Poisonous and Non Poisonous Snakes?

Q5. Comment with suitable example.

1. Harpetology
2. Serpentology
3. Living fossils
4. Antivenin

Q 6. Write short notes on habit, habitat, and distribution of

1. Chelone.
2. Draco.
3. Chameleon
4. Cobra

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UNIT: 9 AVES

CONTENTS

9.1 OBJECTIVE

a) To understand the systematics and functional morphology of various groups of Aves.

b) To study the general characters and classification of Aves.

c) To mak a general study of *Columba (Pigeon).*

d) To study of characters of Archaeopteryx.

e) To study the flight adaptations and bird migration.

9.2 INTRODUCTION

Birds (**Aves**) are a group of endothermic vertebrates, characterized by feathers, toothless beaked jaws, the laying of hard-shelled eggs, a high metabolic rate, a four-chambered heart, and a light weight but strong skeleton. Birds live world wide and range in size from the 5 cm (2 in) bee hummingbird to the 2.75 m (9 ft) Ostrich. They rank as the class of tetra pods with the most living species, at approximately ten thousand, with more than half of these being passerines, sometimes known as perching birds or, less accurately, as song birds.

The fossil record indicates that birds are the last surviving group of dinosaurs, having evolved from feathered ancestors within the theropoda group of saurischian dinosaurs. True birds first appeared during the Cretaceousperiod, around 100 million years ago. DNA based evidence finds that birds diversified dramatically around the time of the Cretaceous–Paleogene extinction event that killed off all other dinosaurs. Birds, especially those in the southern continents, survived this event and then migrated to other parts of the world while diversifying during periods of global cooling.Primitive bird-like dinosaurs that lie outside class Aves proper, in the broader group Avialae, have been found dating back to the mid-Jurassic period. Many of these early "stem-birds", such as Archaeopteryx, were not yet capable of fully powered flight, and many retained primitive characteristics like toothy jaws in place of beaks, and long bony tails.

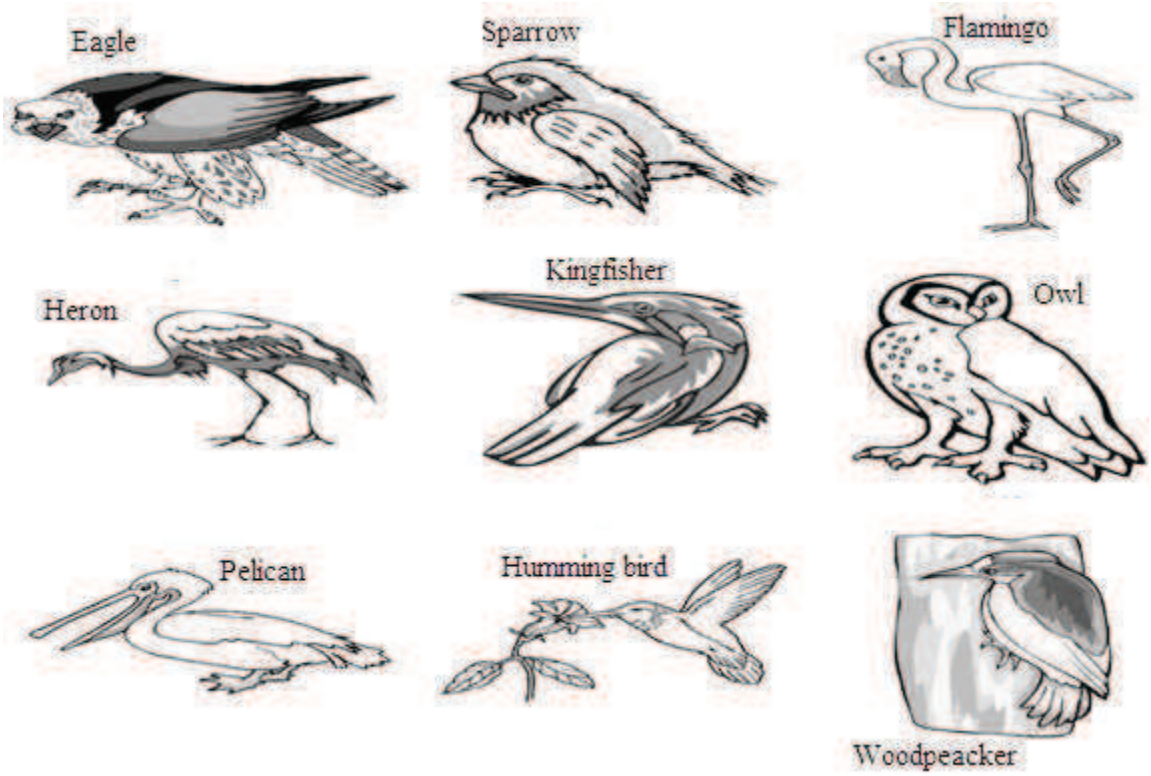

Fig 9.1Different kind of Endothermic vertebrates

Birds have wings which are more or less developed depending on the species; the only known groups without wings are the extinct moss and elephant birds. Wings, which evolved from forelimbs, give most birds the ability to fly, although further speciation has led to some flightless birds, including ratites, penguins, and diverse endemic island species of birds. The digestive and respiratory systems of birds are also uniquely adapted for flight. Some bird species of aquatic environments, particularly the aforementioned flightless penguins, and also members of the duck family, have also evolved for swimming. Birds, specifically Darwin's finches, played an important part in the inception of Darwin's theory of evolution by natural selection.

Some birds, especially corvids and parrots, are among the most intelligent animals; several bird species make and use tools, and many social species pass on knowledge across generations, which is considered a form of culture. Many species annually migrate great distances. Birds are social, communicating with visual signals, calls, and bird songs, and participating in such social behaviors as cooperative breeding and hunting, flocking, and mobbing of predators. The vast majority of bird species are socially monogamous, usually for one breeding season at a time, sometimes for years, but

rarely for life. Other species have polygynous ("many females") or, rarely, polyandrous ("many males") breeding systems. Birds produce offspring by laying eggs which are fertilized through sexual reproduction. They are usually laid in a nest and incubated by the parents. Most birds have an extended period of parental care after hatching. Some birds, such as hens, lay eggs even when not fertilized, though unfertilized eggs do not produce offspring.

Many species of birds are economically important. Domesticated and undomesticated birds (poultry and game) are important sources of eggs, meat, and feathers. Songbirds, parrots, and other

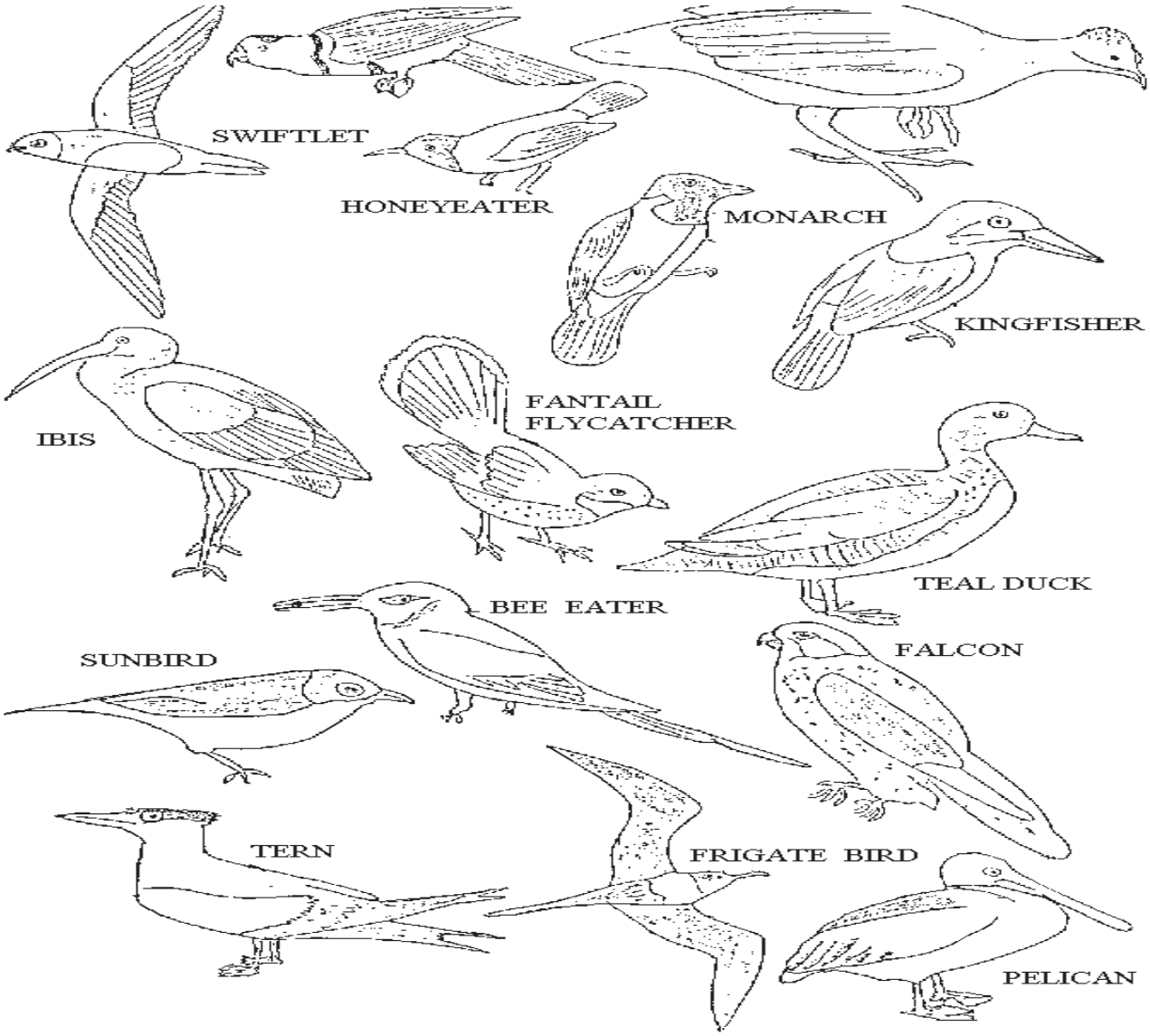

Fig 9.2 Different species of Birds (economically important, domesticated & undomesticated species)

species are popular as pets.Guano (bird excrement) is harvested for use as a fertilizer. Birds prominently figure throughout human culture. About 120–130 species have become extinct due to human activity since the 17th century, and hundreds more before then. Human activity threatens about 1,200 bird species with extinction, though efforts are underway to protect them. Recreational bird watching is an important part of the ecotourism industry.

9.3 GENERAL CHARACTERISTICS OF AVES

Major characteristics of birds:-

Birds compose a diverse class (Aves) of species, as dissimilar as tiny darting humming birds and 8-foot flightless ostriches, with about 9,000 living species known. Generally accepted to have evolved from reptilian dinosaurs, birds share several characteristics with other classes of animals, including a skeletal backbone housing a spinal cord, a four-chambered heart and warmbloodedness. Other of birds' characteristics are unique or essentially unique.

Feathers:-

Feathers are the defining characteristic of Aves, found on every living species of bird and no other class of animal. Feathers are made of keratin, the same substance that forms hair and nails in other animals and are highly modified scales. Feathers are critical not only for flight but also for warmth and protection against the elements -- and in many species, for males to attract mates. Soft, fluffy downy feathers help keep birds warm, contour feathers streamline birds’ bodies and aid in flying, and flight feathers on wings and tail give the bird loft. Birds shed, or molt, old feathers once or twice each year, depending on the species.

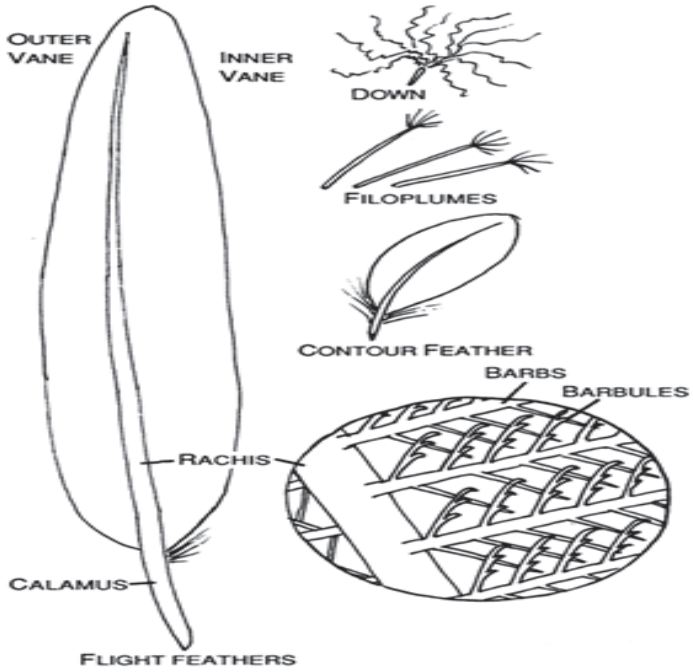

Fig 9.3 Feather of Birds

Wings

All birds have wings, although not all birds fly. Nor are wings confined to Aves; bats are flying mammals and most insects have wings. Birds' bodies are beautifully designed for flight, with strong chest muscles and just enough curves to their wings to provide lift. Differences in wing shape provide different advantages to the various bird species.

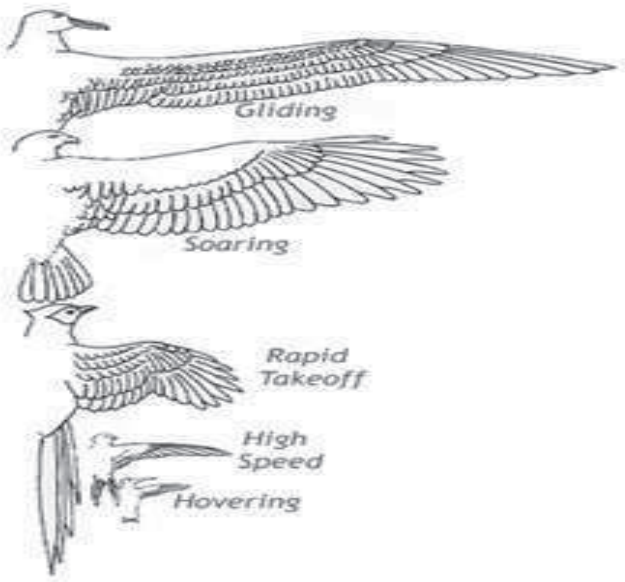

Fig 9.4 Wings of Birds

The narrow, sharp-tipped wings of the falcon provide speed; albatrosses soar high on wings much longer than they are wide. Most songbirds have elliptical, evenly shaped wings that facilitate quick, small movements in the tight spaces of their tree homes. Swimming birds, such as penguins and puffins, have flipper-shaped wings that propel them rapidly and gracefully through water.

Beaks:-

All birds have beaks, or bills, made of a bony core surrounded by a thin layer of keratin. Birds do not have true teeth, but many species have tomia -sharp ridges along the edges of their beaks. Birds do not chew food but grind or rip it into pieces small enough to swallow.

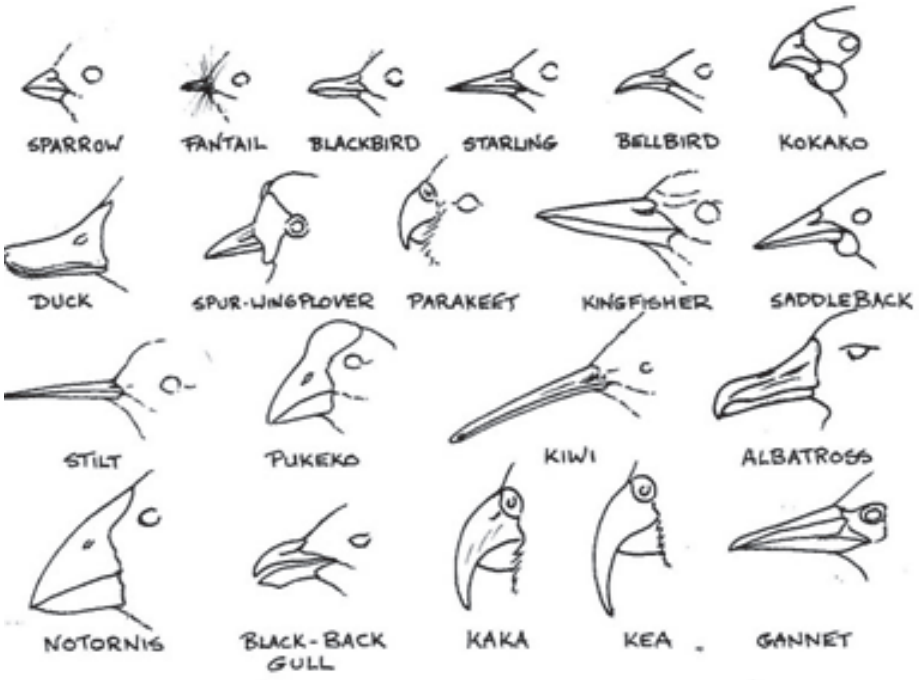

Fig 9.5 Different kind of beaks in Birds

The shape of a bird's beak indicates the bird's general diet. Meat-eaters like hawks and owls have sharp, hooked beaks for ripping and tearing. Strong, cone-shaped beaks help seed eaters break through shells. Ducks and geese have broad, flat beaks for straining food out of the water.

Eggs:-

All birds lay eggs, some very colorful or covered with spots. Eggs are not unique to birds, of course, as fish, reptiles, amphibians and insects also lay eggs. A bird egg has a hard shell made mostly of calcium and a layer of hardened mucus. Inside the egg, the developing embryo receives nutrition from the yolk and the albumin, the egg white. Most birds construct nests to protect their eggs, and then care for the eggs and the hatchlings. The majority of bird species are devoted parents; in most cases, both male and female care for young.

Fig 9.6 Different kind of Eggs in Birds

Skeleton

Most birds have lightweight skeletons with hollow bones. This keeps them light enough for flight. Many fused bones, including the collarbones or wishbones, make birds' skeletons rigid in comparison to mammals'. This helps brace the birds' wings during flight. Their sternums, or breastbones, are large, providing sturdy attachment points for powerful wing muscles. Flightless penguins have heavy bones filled with marrow, helping them to survive in their freezing home range. Ostriches have heavy, solid bones in their legs, helping the birds run and defend themselves with powerful kicks.

9.3.1 CLASSIFICATION

Based on characters, Aves Class is divided into two sub-classes.

Sub class: **i) Archeornithes and Subclass**

ii) Neornithes

Subclass Archeornithes:

1 In this subclass extinct birds are included. Those birds were alive in Mesozoic era.

2 These show a long tail with 13 or more than 13 caudal vertebrae. Pygostyle is absent.

3 Meta carpals are free. The free fingers of fore limb will end with claws. Eg: *Archeopteryx, Archeormis*

Fig 9.6 Example of Subclass Archeornithes

Subclass Neornithes:

1. This subclass includes both extant and extinct birds.
2. Tail ends in pygostyle. The rectrices are arranged r a semicircular aroundpygostyle.
3. Teeth are absent in many forms.
4. Sternum is well developed. It shows a keel to which flight muscles are attached.
5. This subclass is divided into 4 super orders.
6. This subclass is divided into 4 super orders.

Neornithes

1. Odontognathae
2. Palaeognathe
3. Impennae
4. Neognathae

Super order - Palaeognathae.

1 These are flightless birds.

2 They are more in numbers.

3 Wings are reduced or absent.

4 Teeth are absent.

5 Caudal vertebrae are free.

This super order is divisible into 7 orders.

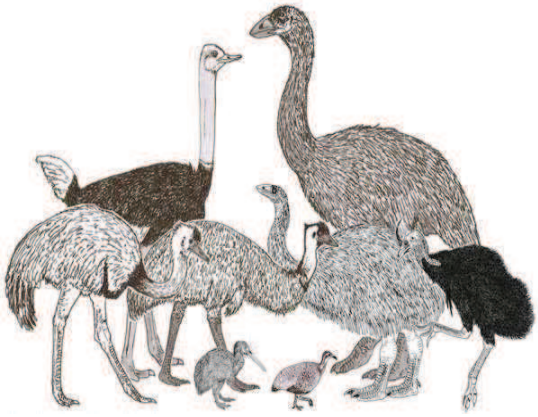

Fig 9.7 Flightless Birds

Order (1) Struthioniformes:

Ex, Struthiocamelus (Two toed African Ostrich (or) Ostrich)

1 Large flight-less bird.

2 Feathers are less.

3 They show two toed hind limbs.

4 Sternum is without keel.

5 Neck is very long and flexible.

6 Pygostyle is absent.

7 These birds are good runners.

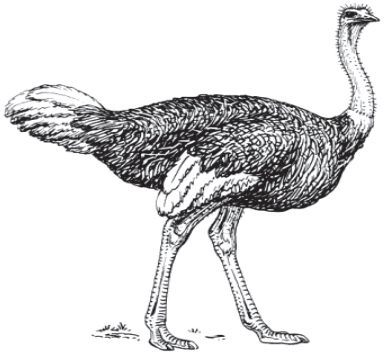

Fig 9.8 Example of Struthioniformes

Order (2) Rheiforms :-

Rhea americana. **(three toed (or) Ameri¬can ostrich).**

1 This includes flightless, terrestrial bird.

2 They are good runners.

3 Wings are better developed.

4 The body shows more feathers.

5 The hind limb bea three toes.

6 Sternum is without keel.

Fig 9.8 Example of Rheiforms

Order (3) Casuariformes.

Ex: Casuarius (Cassowaries) Dromaeus (Emu)

1 These are flightless terrestrial birds. .

2 Head shows few feathers.

3 Neck and body show more feathers.

4 Wings are Rudimentus.

5 The hind limb shows three toes.

Fig 9.9 Example of Casuarius

Order (4) Aepyomithiformes :

Aepyornis.

1 These are extinct elephant birds.

2 Wings are vestigeal.

3 Legs are powerful.
Hindlimbs show 4 toes.

4 Sternum is broad. Keel is absent.

5 Eggs are very big.

Order (5) Dinomithiformes:

Ex : Dinornis (Extinct) (Moas)

1 These are gaint flightless extinct birds.

2 Wings are absent.

3 Eggs are massive.

4 Sternum is reduced without keel.

5 Pectoral girdle is absent.

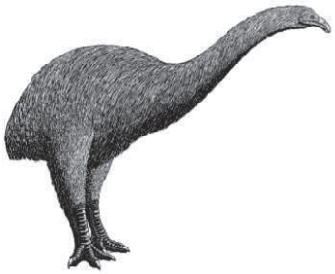

Fig 9.10 Dinornis

Order (6)Apternygiformes

Ex : Apteryx (Kiwi). Newzeland bird

1. These are flightless, terrestrial birds.
2. Wings are rudimentary.
3. Eyes are small.
4. Neck and legs vet small.
5. Hind limbs bear 4 toes.
6. These are Nocturnal. They feed on inserts.
7. Eggs are largest relatively.
8. These are present only in Newzeland and Australia. Fig 9.11 Apteryx (Kiwi)

Order(7)Tinamiformes

Ex :Tinamus.

1 These are small, terrestrial with little power of flight.

2 Wings are short and round.

3 Pygostyle is reduced.

4 Eggs are big.

5 They eat plant products.

Fig 9.12Tinamus

Super Order Impennae:-

This super order includes flightless aquatic birds.

1. Their foreKmbs are modified into paddles.

This super order includes only one order.

Order Sphenisciformes (SPHENISCI FORMES)

Ex: *Aptenodyts (Penguin)*

1. These are flightless aquatic birds.
2. Feathers are small scale like. They Cover the. Entire body.
3. Forelimbs are modified into paddles. And They are useful for swimming
4. Limbs are 4 toes.
5. Below the skin thick layer of fat will be present.

Fig 9.13Aptenodyts (Penguin)

Super order: Neognathae:

1 This sub order includes modern flying birds.

2 Teeth are absent. –

3 Wings are well developed.

4 Sternum shows keel.

5 Flight muscles are well devebped.

6 Pygostyle is present.

This super order is divisible into the following orders.

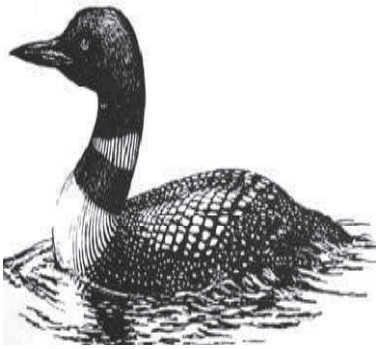

Fig 9.14Example of Super order: Neognathae

Order 1 :Gaviformea

Ex : Gaviaimmer (Common loon)

1 These birds show powerful fight

2 Toes are webbed.

Fig 9.15 Common loon

Order 2 :Podlcipit formes

:

Ex :Podiceps.

1 These are fresh water birds.

2 Feet are lobed.

Fig 9.16 Podiceps

Order 3 :Procellariiformes :

Ex : Puffinus (Petrels, Diomedia) (Wandering albatross)

1 Skull shows large nasal gland.

2 Feathers are compact.

3 Wings are long and narrow.

Fig 9.17 Puffinus

Order4 :Pelecaniformee

Ex : Pelecanus (Pelecan)

1 Aquatic fish eating birds.

2 Four toes are webbed.

Order5 :Clconiformee :

Ex: Ardea (great blue heron)

1 Neck is long and Legs are long,

2 Web is absent.

Order6 :Ariseriformea :

Ex : Anserdomesticus (Duck), Cygnus (swan)

1 Beak is broad.

2 Tongue is fleshy.

3 Legs are short.

4Feet are webbed.

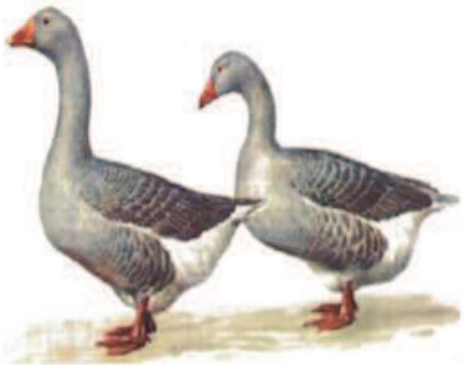

Fig 9.18 Duck

Order 7 : FaiconlformeA:

Ex : Mihmsmigrans (Kite). Pseudogyps (Vulture)

1 Beak is short and curved.

2 Feet show curved daws.

3 They are strong fleers.

Fig 9.19 Vulture

Order 8 : Galliforroea :

Ex GaOus (Jungle owl), Pavocristatus (Peacock)

1 Beak is short.

2 Terrestrial birds.

3 They will fly.

Order 9: Gruiformes :

Ex Grus (crane)

1 They are small or medium large-size birds.

2 They may be weak or strong fliers.

3 Legs are long.

Fig 9.20 Grus (crane)

Order 10 Diatrymiformee;

1 These are extinct birds.

Order 11: - Chardriiforrae

Ex:Larus (Gull)

1. Shore dwelling aquatic birds.
2. Toes are webbed.

Order 12 : Columbiformes :

Ex : 1. Columba livia (Pigeon) 2. Sterptopelia (Dove)

1 Skin thick and soft.

2 Beak is usually short and slender.

3 Crop produces pigeon milk to feed the young ones.

Order 13 :Cuculiformee :

Ex : .1. Cuculus (cuckoo) 2. Eudynamis (Koel)

1 Many Cuckoos are parasites.

2 The females lay their eggs in the nests of other birds.

3 The toes are four in number.

4 Tail is long.

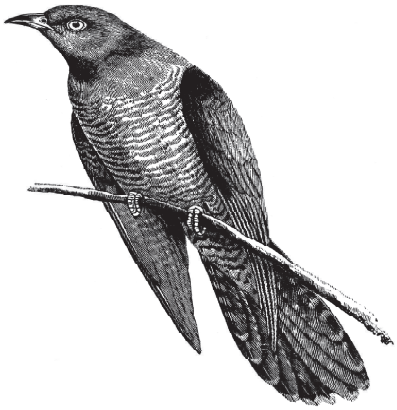

Fig 9.21 Koel

Order 14: Paitiaciforme :

Ex : Psittaculaeupatra (Parra keet)

1 Feathers are green, blue, yellow.

2 Beak is short and curved.

3 Frugivorus forms.

Order 15: Strlgiformes :

Ex : Bubo bubo (green horned owl)

1 Head is large and narrow.

2 Retina contains many rods. Hence it can see in the night time.

3 They are nocturnal predators.

Fig 9.22 Green horned owl

Order 16: Caprimulgiformee:

Ex: Caprinulgus (Night jar)

1 Legs are weak.

2 Beak is small.

Fig 9.23 Night jar

Order 17 :Apodiformes :

Ex : Swift (Humming bird)

1 These are small birds.

2 They are powerful fliers.

Fig 9.24 Swift (Humming bird)

Order 18 :Coliifbrmee :

Ex : Cobus (Mouse bird)

1 Small birds.

2 Tail is long.

Order 19 :Coraciformes :

Ex : Akedo king fisher and hornbill

1 Beak is strong. It is useful to catch fishes.

2 Third and Fourth toes are fused at the base.

Fig 9.25Akedo king fisher and hornbill

Order 20 :Piciforme :

Ex : Brachypternus (Wood pecker)

1 Dinopium (Wood pecker)

2 Tail feathers are pointed.

Order 21 : Passed formes :

1 Passer domesticus (Sparrow)

2 Corvus (Crow)

3 Acridotherus (Myna)

Fig 9.26 Sparrow

9.4. GENERAL STUDY OF COLUMBA (PIGEON)

Systamatic Position

Phylum	-Chordata
Subphylum	- Vertebrata
Superclass	-Tetrapoda
Class	-Aves
Subclass	-Neornithes
Superorder	- Neognathae
Order	-Columbiformes
Type	-Columba livia

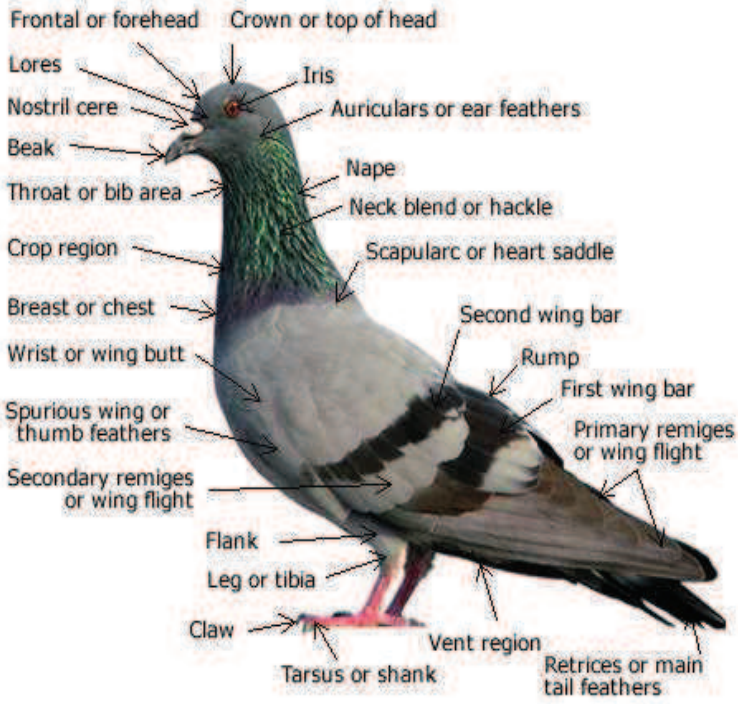

Fig 9.27 Pigeon

The large bird Columba (Pigeon) comprises a group of medium to large stout-bodied pigeons, often referred to as the typical pigeons. The terms "dove" and "pigeon" are used indiscriminately for smaller and larger Columbidae, respectively. Columbaspecies – at least those of Columba sensustricto – are generally termed "pigeons", and in many cases wood-pigeons. The species commonly referred to just as "the pigeon" is the feral pigeon (C. liviadomestica). It is derived from the rock pigeon(C. livia), which also has given rise to the majority of domesticated pigeon breeds, such as the racing pigeon. Meanwhile, "wood pigeon" by itself usually means the common wood pigeon (C. palumbus).

This genus as understood today is native to the Old World, but some – notably the domestic and feral rock pigeon – have been introduced outside their natural range, for example in the Americas.

Etymology

The term *columba* comes from the Latin *columba*, "a dove", the feminine form of *columbus*, "a male dove",itself the latinisation of the Greek (*kolumbos*), "diver", which derives from the verb (*kolumbaō*), "to dive, plunge headlong, swim". The feminine form of *kolumbos*, (*kolumbis*), "diver", was the name applied by Aristophanesand others to the common rock pigeons of Greece, because of the "swimming" motion made by their wings when flying.

Systematic

The American pigeons formerly in Columba are now split off as a separate genus Patagioenas again. That the American radiation constitutes a distinct lineage is borne out by molecular evidence; in fact, the Patagioenas "pigeons" are basal to the split between the Columba "pigeons" and the Streptopelia "doves". The typical pigeons together with Streptopelia and the minor Nesoenas and Stigmatopelia lineages constitute the dominant evolutionary radiation of Columbidae in temperateEurasia, though they also occur in tropical regions. The taxonomic status of some African pigeons presently placed here is in need of further study; they are smaller than the usual Columba (and hence often called "doves"), and differ in some other aspects. They might be separable as genus Aplopelia. That notwithstanding, the lineage of the typical pigeons probably diverged from its closest relatives in the Late Miocene, perhaps some 7-8 million years ago .

9.5 CHARACTERS OF ARCHAEOPTERYX

Scientific Position:

Kingdom : Animalia

Phylum: Chordata

Clade: Dinosauria

Order: Saurischia

Suborder: Theropoda

Clade: Avialae

Family: Archaeopterygidae

Genus : Archaeopteryx

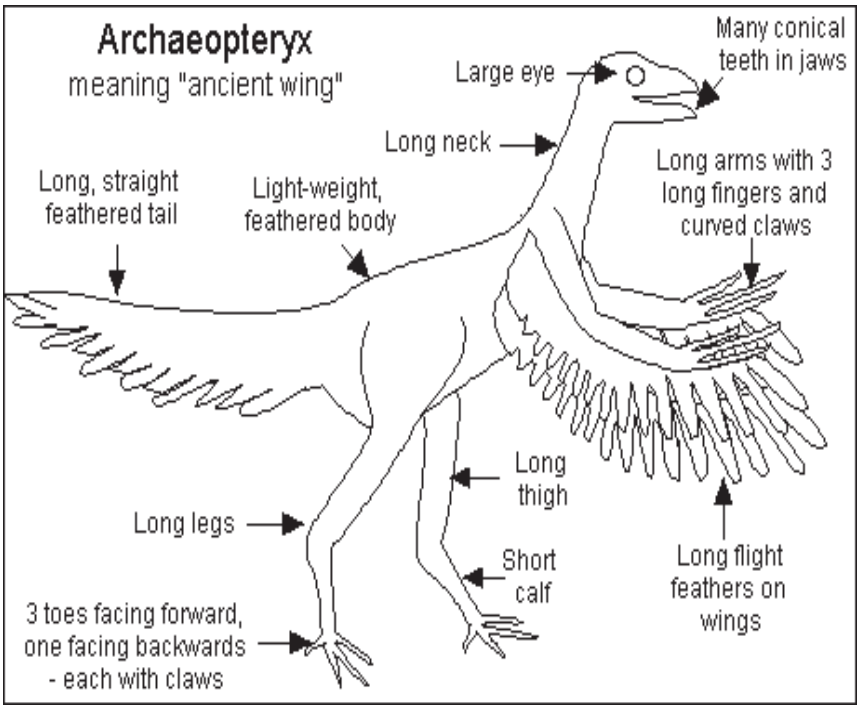

Fig 9.28 Archaeopteryx

Archaeopteryx, sometimes referred to by its German name Urvogel ("original bird" or "first bird"), is a genus of bird-like dinosaurs that is transitional between non-avian feathered dinosaurs and modern birds. The name derives from the ancient Greek meaning "ancient", and meaning "feather" or "wing". Between the late nineteenth century and the early twenty-first century, Archaeopteryx had been generally accepted by palaeontologistsand popular reference books as the oldest known bird (member of the group Avialae).Older potential avialans have since been identified, including Anchiornis, Xiaotingia, and Aurornis.

Archaeopteryx lived in the Late Jurassic around 150 million years ago, in what is now southern Germany during a time when Europe was an archipelago of islands in a shallow warm tropical sea, much closer to the equator than it is now. Similar in size to a Eurasian magpie, with the largest individuals possibly attaining the size of a raven, the largest species ofArchaeopteryx could grow to about 0.5 m (1 ft 8 in) in length. Despite their small size, broad

wings, and inferred ability to fly or glide, Archaeopteryx had more in common with other small Mesozoic dinosaurs than with modern birds. In particular, they shared the following features with the dromaeosaurids and troodontids: jaws with sharp teeth, three fingers with claws, a long bony tail, hyperextensible second sstoes ("killing claw"), feathers (which also suggest warm-bloodedness), and various features of the skeleton.

These features make *Archaeopteryx* a clear candidate for a transitional fossil between non-avian dinosaurs and birds.Thus, *Archaeopteryx* plays an important role, not only in the study of the origin of birds, but in the study of dinosaurs. It was named from a single feather in 1861.[8] That same year, the first complete specimen of *Archaeopteryx* was announced. Over the years, ten more fossils of *Archaeopteryx* have surfaced. Despite variation among these fossils, most experts regard all the remains that have been discovered as belonging to a single species, although this is still debated.

Most of these eleven fossils include impressions of feathers. Because these feathers are of an advanced form (flight feathers), these fossils are evidence that the evolution of feathers began before the Late Jurassic. The type specimen of*Archaeopteryx* was discovered just two years after Charles Darwin published On the Origin of Species. *Archaeopteryx*seemed to confirm Darwin's theories and has since become a key piece of evidence for the origin of birds, the transitional fossils debate, and confirmation of evolution.

9.6 FLIGHT ADAPTATION & BIRD MIGRATION

Bird migration is the regular seasonal movement, often north and south along a flyway, between breeding andwintering grounds. Many species of bird migrate. Migration carries high costs in predation and mortality, including from hunting by humans, and is driven primarily by availability of food. It occurs mainly in the northern hemisphere, where birds are funnelled on to specific routes by natural barriers such as the Mediterranean Seaor the Caribbean Sea.

Historically, migration has been recorded as much as 3,000 years ago by Ancient Greek authors including Homer and Aristotle, and in the Book of Job, for species such as storks, turtle doves, and swallows. More recently, Johannes Leche began recording dates of arrivals of spring migrants in Finland in 1749, and scientific studies have used techniques including bird ringing and satellite tracking. Threats to migratory birds have grown with habitat destruction

especially of stopover and wintering sites, as well as structures such as power lines and wind farms.

The Arctic tern holds the long-distance migration record for birds, travelling between Arctic breeding grounds and the Antarctic each year. Some species of tubenoses (Procellariiformes) such as albatrosses circle the earth, flying over the southern oceans, while others such as Manx shearwaters migrate 14,000 km (8,700 mi) between their northern breeding grounds and the southern ocean. Shorter migrations are common, including altitudinal migrations on mountains such as the Andes and Himalayas.

The timing of migration seems to be controlled primarily by changes in day length. Migrating birds navigate using celestial cues from the sun and stars, the earth's magnetic field, and probably also mental maps.

Swallow migration versus hibernation:-

Aristotle however suggested that swallows and other birds hibernated. This belief persisted as late as 1878, when Elliott Coues listed the titles of no less than 182 papers dealing with the hibernation of swallows. Even the "highly observant"Gilbert White, in his posthumously published 1789 The Natural History of Selborne, quoted a man's story about swallows being found in a chalk cliff collapse "while he was a schoolboy at Brighthelmstone", though the man denied being an eyewitness.However, he also writes that "as to swallows being found in a torpid state during the winter in the Isle of Wight or any part of this country, I never heard any such account worth attending to", and that if early swallows "happen to find frost and snow they immediately withdraw for a time—a circumstance this much more in favor of hiding than migration", since he doubts they would "return for a week or two to warmer latitudes".

General patterns:-

Migration is the regular seasonal movement, often north and south, undertaken by many species of birds. Bird movements include those made in response to changes in food availability, habitat, or weather. Sometimes, journeys are not termed "true migration" because they are irregular (nomadism, invasions, irruptions) or in only one direction (dispersal, movement of young away from natal area). Migration is marked by its annual seasonality. Non-migratory birds are said to be resident or sedentary. Approximately 1800 of the world's 10,000 bird species are long-distance migrants.

Many bird populations migrate long distances along a flyway. The most common pattern involves flying north in the spring to breed in the temperate or Arctic summer and returning in the autumn to wintering grounds in warmer regions to the south. Of course, in the southern hemisphere the directions are reversed, but there is less land area in the far south to support long-distance migration.

The primary motivation for migration appears to be food; for example, some hummingbirds choose not to migrate if fed through the winter. Also, the longer days of the northern summer provide extended time for breeding birds to feed their young. This helpsdiurnal birds to produce larger clutches than related non-migratory species that remain in the tropics. As the days shorten in autumn, the birds return to warmer regions where the available food supply varies little with the season.

These advantages offset the high stress, physical exertion costs, and other risks of the migration. Predation can be heightened during migration: Eleonora's falcon Falco eleonorae, which breeds on Mediterranean islands, has a very late breeding season, coordinated with the autumn passage of southbound passerine migrants, which it feeds to its young. A similar strategy is adopted by the greater noctule bat, which preys on nocturnal passerine migrants. The higher concentrations of migrating birds at stopover sites make them prone to parasites and pathogens, which require a heightened immune response.

Within a species not all populations may be migratory; this is known as "partial migration". Partial migration is very common in the southern continents; in Australia, 44% of non-passerine birds and 32% of passerine species are partially migratory.In some species, the population at higher latitudes tends to be migratory and will often winter at lower latitude. The migrating birds bypass the latitudes where other populations may be sedentary, where suitable wintering habitats may already be occupied. This is an example of leap-frog migration.Many fully migratory species show leap-frog migration (birds that nest at higher latitudes spend the winter at lower latitudes), and many show the alternative, chain migration, where populations 'slide' more evenly north and south without reversing order.

Long-Distance Migration:-

The typical image of migration is of northern landbirds, such as swallows (Hirundinidae) and birds of prey, making long flights to the tropics. However, many Holarctic wildfowl and finch (Fringillidae) species winter in the North Temperate Zone, in regions with milder winters than their summer breeding grounds. For example, the pink-footed goose *Anserbrachyrhynchus* migrates from Iceland to Britain and neighbouring countries, while the dark-eyed junco Juncohyemalismigrates from subarctic and arctic climates to the contiguous United States and the American goldfinch from taiga to wintering grounds extending from theAmerican South northwestward to Western Oregon.Migratory routes and wintering grounds are traditional and learned by young during their first migration with their parents. Some ducks, such as the garganey Anasquerquedula, move completely or partially into the tropics. The European pied flycatcher Ficedulahypoleucaalso follows this migratory trend, breeding in Asia and Europe and wintering in Africa.

Often, the migration route of a long-distance migrator bird doesn't follow a straight line between breeding and wintering grounds. Rather, it could follow a hooked or arched line, with detours around geographical barriers. For most land-birds, such barriers could consist in seas, large water bodies or high mountain ranges, because of the lack of stopover or feeding sites, or the lack of thermal columns for broad-winged birds.

In waders

A similar situation occurs with waders (called *shorebirds* in North America). Many species, such as dunlin *Calidrisalpine*and western sandpiper *Calidrismauri*, undertake long movements from their Arctic breeding grounds to warmer locations in the same hemisphere, but others such as semipalmated sandpiper *C. pusilla* travel longer distances to the tropics in the Southern Hemisphere.

Fig 9.29 Shorebirds in North America

For some species of waders, migration success depends on the availability of certain key food resources at stopover points along the migration route. This gives the migrants an opportunity to refuel for the next leg of the voyage. Some examples of important stopover locations are the Bay of Fundy and Delaware Bay.

Some bar-tailed godwits *Limosalapponica* have the longest known non-stop flight of any migrant, flying 11,000 km fromAlaska to their New Zealand non-breeding areas.Prior to migration, 55 percent of their bodyweight is stored as fat to fuel this uninterrupted journey.

Diurnal migration in raptors:-

Some large broad-winged birds rely on thermal columns of rising hot air to enable them to soar. These include many birds of prey such as vultures, eagles, and buzzards, but also storks. These birds migrate in the daytime. Migratory species in these groups have great difficulty crossing large bodies of water, since thermals only form over land, and these birds cannot maintain active flight for long distances. Mediterranean and other seas present a major obstacle to soaring birds, which must cross at the narrowest points. Massive numbers of large raptors and storks pass through areas such as the Strait of Messina, Gibraltar, Falsterbo, and the Bosphorus at migration times. More common species, such as the European honey buzzard *Pernisapivorus*, can be counted in hundreds

of thousands in autumn. Other barriers, such as mountain ranges, can also cause funnelling, particularly of large diurnal migrants. This is a notable factor in the Central Americanmigratory bottleneck. Batumi bottleneck in the Caucasus is one of the heaviest migratory funnels on earth. Avoiding flying over the Black Sea surface and across high mountains, hundreds of thousands of soaring birds funnel through an area around the city of Batumi, Georgia. Birds of prey such as honey buzzards which migrate using thermals lose only 10 to 20% of their weight during migration, which may explain why they forage less during migration than do smaller birds of prey with more active flight such as falcons, hawks and harriers.

Nocturnal migration in smaller insectivorous birds:-

Many of the smaller insectivorous birds including the warblers, hummingbirds and flycatchers migrate large distances, usually at night. They land in the morning and may feed for a few days before resuming their migration. The birds are referred to as *passage migrants* in the regions where they occur for short durations between the origin and destination.

Nocturnal migrants minimize predation, avoid overheating, and can feed during the day.One cost of nocturnal migration is the loss of sleep. Migrants may be able to alter their quality of sleep to compensate for the loss.

Short-distance and altitudinal migration:-

Many long-distance migrants appear to be genetically programmed to respond to changing day length. Species that move short distances, however, may not need such a timing mechanism, instead moving in response to local weather conditions. Thus mountain and moorland breeders, such as wallcreeper *Tichodromamuraria* and white-throated dipper *Cincluscinclus*, may move only altitudinally to escape the cold higher ground. Other species such as merlin *Falco columbarius* and Eurasian skylark *Alaudaarvensis* move further, to the coast or towards the south. Species like the chaffinch are much less migratory in Britain than those of continental Europe, mostly not moving more than 5 km in their lives.

Fig 9.30 Short distance migration in birds

Short-distance passerine migrants have two evolutionary origins. Those that have long-distance migrants in the same family, such as the common chiffchaff *Phylloscopuscollybita*, are species of southern hemisphere origins that have progressively shortened their return migration to stay in the northern hemisphere.

Species that have no long-distance migratory relatives, such as the waxwings *Bombycilla*, are effectively moving in response to winter weather and the loss of their usual winter food, rather than enhanced breeding opportunities.

In the tropics there is little variation in the length of day throughout the year, and it is always warm enough for a food supply, but altitudinal migration occurs in some tropical birds. There is evidence that this enables the migrants to obtain more of their preferred foods such as fruits.

Altitudinal migration is common on mountains worldwide, such as in the Himalayas and the Andes.

Irruptions and dispersal

Sometimes circumstances such as a good breeding season followed by a food source failure the following year lead to irruptions in which large numbers of a species move far beyond the normal range. Bohemian waxwings *Bombycillagarrulous* well show this unpredictable variation in annual numbers, with five major arrivals in Britain during the nineteenth century, but 18

between the years 1937 and 2000. Red crossbills *Loxiacurvirostra* too are irruptive, with widespread invasions across England noted in 1251, 1593, 1757, and 1791.

Evolutionary and ecological factors:-

Migration in birds is highly labile and is believed to have developed independently in many avian lineages. While it is agreed that the behavioral and physiological adaptations necessary for migration are under genetic control, some authors have argued that no genetic change is necessary for migratory behavior to develop in a sedentary species because the genetic framework for migratory behavior exists in nearly all avian lineages. This explains the rapid appearance of migratory behavior after the most recent glacial maximum.

Climate change:-

Large scale climatic changes, as have been experienced in the past, are expected to have an effect on the timing of migration. Studies have shown a variety of effects including timing changes in migration, breeding as well as population variations.

Ecological effects:-

The migration of birds also aids the movement of other species, including those of ectoparasites such as ticks and lice, which in turn may carry micro-organisms including those of concern to human health. Due to the global spread of avian influenza, bird migration has been studied as a possible mechanism of disease transmission, but it has been found not to present a special risk; import of pet and domestic birds is a greater threat.Some viruses that are maintained in birds without lethal effects, such as the West Nile Virus may however be spread by migrating birds. Birds may also have a role in the dispersal of propagules of plants and plankton.

9.7 SUMMARY

Aves are the Latin name for the birds - feathered, winged bipedal, warm-blooded, egg-laying, vertebrate animals with evolutionary origins among the reptiles. The taxon has been historically treated as equal to fish, amphibian, reptiles and mammals, but in order to make classifications reflect evolutionary history, they are now more usually regarded as falling inside the Reptilian. Around 10,000 living species makes them the most species class of tetra pod vertebrates. They inhabit ecosystems across the globe, from the Arctic to the Antarctic. Extant birds range in size from the 5 cm Bee Hummingbird to the 2.75 m Ostrich. The fossil record indicates that birds evolved from there of dinosaurs during the Jurassic period, around 160 million years (Ma) ago. Birds are the only clade of dinosaurs to have survived the Cretaceous "Paleogene extinction event 65.5 Ma ago. Modern birds are characterized by feathers, a beak with no teeth, the laying of hard-shelled eggs, a high metabolic rate, a four-chambered heart, and a lightweight but strong skeleton. All living species of birds have wings. Wings are evolved forelimbs, and most bird species can fly; exceptions include the ostriches, emus and relatives, penguins, and some endemic island species. Birds also have unique digestive and respiratory systems that are well suited to their flying needs. Some birds, especially corvids and parrots, are among the most intelligent animal species; a number of bird species have been observed manufacturing and using tools, and many social species transmit knowledge across generations. Many species undertake long distance annual migrations, and many more perform shorter irregular movements.Many species are social and communicate using visual signals and through calls and songs, and participate in social behaviours, including cooperative breeding and hunting, flocking, and mobbing of predators. The vast majority of bird species are socially monogamous, usually for one breeding season at a time, sometimes for years, and rarely for life. Other species have polygynous (\"many females\") or, rarely, polyandrous (\"many males\") breeding systems. Eggs are usually laid in a nest and incubated by the parents. Most birds have an extended period of parental care after hatching. Many species are of economic importance, mostly as sources of food acquired through hunting or farming. Some species, particularly songbirds and parrots, are popular as pets. Other uses include the harvesting of guano (droppings) for use as a fertiliser. Birds figure prominently in all aspects of human culture from religion to poetry to popular

music. About 120â "130 species have become extinct as a result of human activity since the 17th century and hundreds more before then. Currently about 1,200 species of birds are threatened with extinction by human activities, though efforts are underway to protect them.

9.8 GLOSSARY

Asymmetric - Not the same on each side of the body

Atmospheric pollution -Pollution of the air

Aves - the Latin word for birds; a special class of vertebrates

Binocular vision - seeing only one object at a time; both eyes focus on the same object

Bird of prey - a carnivorous bird (hawk, falcon, eagle, etc.) that kills and eats small Mammals and other birds

Botulism - Poisoning from spoiled food

Carnivore - Meat eater

Carrion - decaying flesh of a dead body

Cere - fleshy area above the beak, where the nostrils of most birds are located

Cold-Blooded- animals that can only control their body temperatures by moving into warmer or cooler areas

Concave- Wings that is flat or slightly curved on the bottom

Cones - Cells of the eye sensitive to color

Conserving Energy -To keep from using energy by resting or gliding when possible

Contour Feathers- stiff feathers designed to cover the wings and body of a bird

Convex- Wings that are curved on top

Crop- a large sac between the esophagus and stomach that stores food until the Bird is ready to begin digestion

Diurnal - Daytime hunters

Domestic - Any animal used by man - not wild

Down Feathers - fluffy feathers designed to help insulate and keep a bird warm

Drag - anything that hinders or hampers the speed; something that pulls you Down

Electrocution- Injury or death from electricity

Environmental Contamination- Pollution of the environment

Esophagus- Portion of the body that connects the mouth with the stomach

Falconiformes- Related to falcons; hawks, osprey, eagles, etc

Fledge - the rearing of a young bird until it has grown its feathers and is able to fly And leave the nest

Flight Feathers- special contour feathers that help a bird get off the ground, move in the air, And land safely

Foragers- Scavenge for food - eats discarded food

Fovea - a rodless area of the retina enabling a bird of prey acute vision

Gizzard - a special muscle of the stomach that helps the digestive process by grinding and crushing hard-to-digest food; acts like teeth

Incubating - Keep eggs warm until hatching.

9.9 TERMINAL QUESTION ANSWERS

Q1 Give the classification on the order level of Pigeon.

Q2 Give the introduction of Pigeon.

Q3 Explain the different type of migration.

Q4 Give an account of flight mechanism in birds.

Q5 Give an account of structure an affinities of Archaeopteryx?

Multiple Choice Questions

1 The study of birds is termed as:

(a) Ornithology

(b) Oology

(c) Herpetology

(d) Ichthyology

2 Witch of the following is not true for birds

(a) Feathered

(b) Flying

(c) Quadraped

(d) Possess wing

3 The only cutaneous gland in pigeon

(a) Sweat gland

(b) Sebaceous gland

(c) Mammary gland

(d) Preen gland uropygial gland

4 In bird gizzard is used

(a) Chewing food

(b) Grinding food

(c) Mixing food

(d) Digesting food

5 In birds voluntary movements are controlled by:

(a) Cerebellum

(b) Optic lobes

(c) Cruracerbri

(d) Medulla oblongata

6 In birds, sound is produced by:

(a) Air sac

(b) Trachea

(c) Larynx

(d) Syrinx

7 The fossil record of Archaeopteryx have been discovered from:

(a) Britain

(b) Germany

(c) France

(d) USA

8 Birds are glorified

(a) Vertebrates

(b) Fishes

(c) Amphibians

(d) Reptiles

9 The most common mode of flight

(a) Flapping

(b) Gliding

(c) Soaring

(d) Hovering

10 Beak in sparrows is

(a) Cutting type

(b) Seed eating type

(c) Fruit eating type

(d) Tearing and piercing type

Answers

1(a)2(c) 3(d)4(b)5(d)6 (d)7 (b)8(d)9(a)10(b)

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UNIT: 10 MAMMALIA

CONTENT

10.1 OBJECTIVE

a) To understand the systematics and functional morphology of various groups of Mammalia.
b) To study the general characters and classification of class Mammalia.
c) To study the affinities of Prototheria, Metatheria and Eutheria.
d) To Study a type specimen of mammalia- Rabbit.
e) To study the dentition in mammals.
f) To study and economic importance of mammals.

10.2 INTRODUCTION

Mammals include the largest animals on the planet, the great whales, as well as some of the most intelligent, such as elephants, primates and cetaceans. The basic body type terrestrial quadruped, but some mammals are adapted for life in sea, in the air, on trees, underground or on two legs. The largest group of mammals, the placental, have a placenta, which enables range in size from the 30–40 mm (1.2–1.6 in) (108 ft) blue whale,With the exception of the five species of monotreme (egg-laying mammals), all modern mammals give birth to live young. Most mammals, including the six most species-rich orders, belong to the placental group. The three largest orders in number of species are Rodentia i.e mice, rats, porcupines, beavers, capybaras and other gnawing mammals; Chiroptera i.e bats; and Soricomorpha: shrews, moles and solenodons. The next three biggeorders, depending on the biological classification scheme used, are the Primates including the great apes and monkeys; the Cetartiodactyla including whales and even-toed ungulates; and the Carnivora which includes cats, dogs, weasels, bears and seals The word "mammal" is modern, from the scientific name Mammalia, coined by **Carl Linnaeus in 1758,** derived from the Latin mamma ("teat, pap"). All female mammals nurse their young with milk, which is secreted from special glands, i.e mammary glands. According to Mammalian Species of the World, 5,416 species were known in 2006. These were grouped in 1,229 genera, 153 families and 29 orders. In 2008 the International Union for Conservation of Nature (IUCN) completed a five-year, 1,700-scientist Global Mammal Assessment for its IUCN Red List, which counted 5,488 species. In

some classifications, extant mammals are divided into two subclasses: the Prototheria, that is, the order Monotremata; and the Theria, or the infraclasses Metatheria and Eutheria. The marsupials constitute the crown group of the Metatheria, and include all living metatherians as well as many extinct ones; the placentals are the crown group of the Eutheria. While mammal classification at the family level has been relatively stable, several contending classifications regarding the higher levels subclass, infraclass and order.

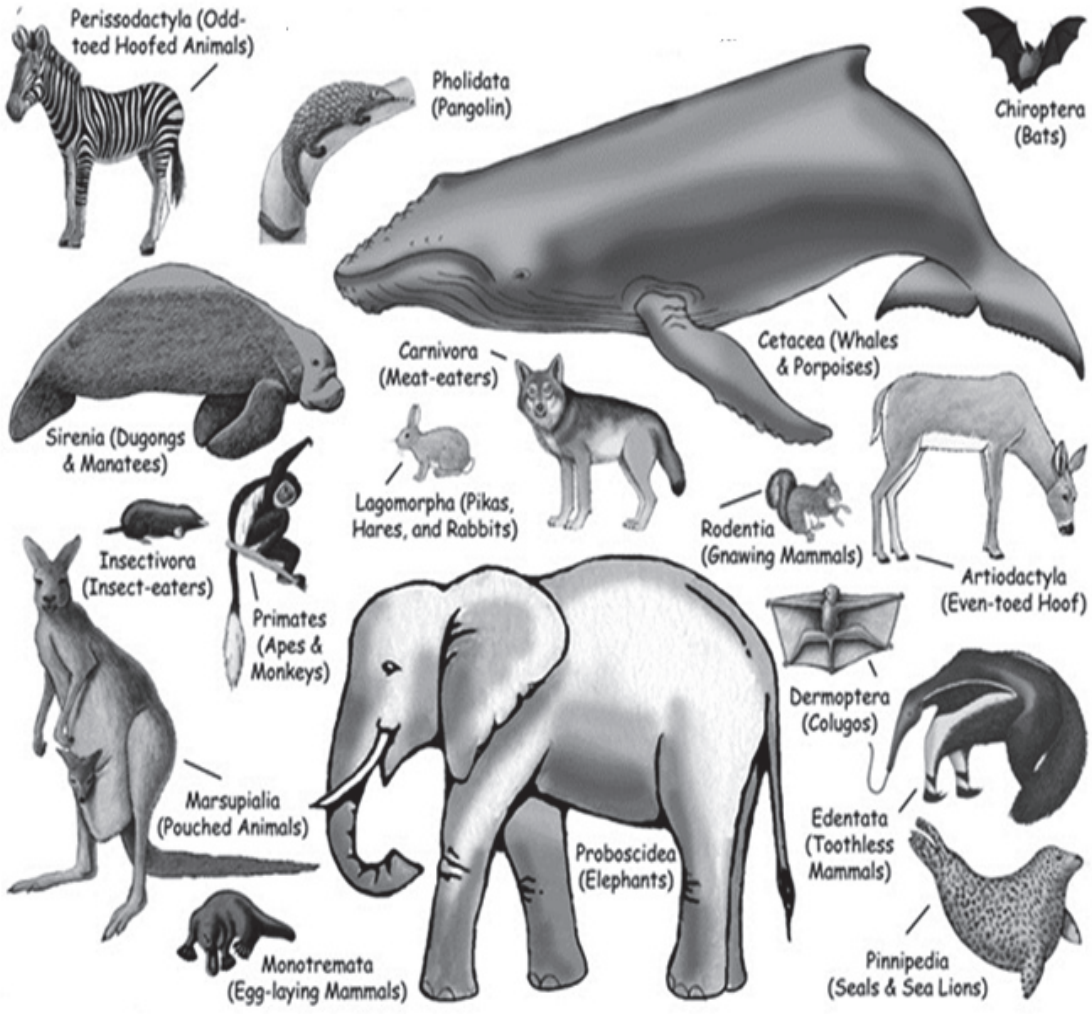

Fig 10.1 Animals of the class mammalian(Mammals)

10.3 GENERAL CHARACTERISTICS OF MAMMALIA

Characteristics of Class Mammalia are given below:-

a) They are Warm blooded.
b) Possess hair which is made of keratin. The evolution of mammalian keratin is believed to be independent of reptilian keratin. Hair provides insulation.
c) Endothermic. The majority of the heat energy is used to maintain their high body temperature.
d) Four chambered heart.
e) Mammary glands are used to produce milk to nourish their young. Female glands are the only functional glands.
f) Thediaphragm is a muscle that separates the thoracic cavity from the abdominal cavity.
g) Seven cervical vertebrae (neck bones) are present in most mammals.
h) Most are viviparous though some are oviparous. An extended gestation period uterine development is common in most placental mammals.
i) Teeth are imbedded in the jaw bone and come in a variety of forms.
j) Well-developed brain.
k) Mammals developed from the therapsid ancestors during the Triassic period.
l) Mammals are heterodontic, meaning that their teeth are different shapes, except those with no teeth at all.
m) Reptiles and fish have teeth that are all basically the same, though they can vary in size throughout the mouth. See image above.
n) The Buccal Cavity (the mouth) has a false palate as a roof, meaning that the nostrils do not lead directly into his mouth.
o) The body is maintained at a constant temperature they generate heat within their bodies metabolically and also have special cooling mechanisms.
p) Highly developed neopallium.
q) Tectum reduced to corpora quadrigemina: functions mainly as a relay center for auditory information and to control visual reflexes.
r) Corpus callosum in eutherians provides additional communication
s) Smell acute except whales and higher apes.

t) Eye typical of amniotes.
u) Tapetum lucidum well developed in nocturnal mammals.
v) Touch- most have vibrissae that are controlled by facial muscles.
w) Lateral movement of jaw during mastication.
x) Viviparous except monotremes which are egg laying.
y) Parental care well developed.

10.4 CLASSIFICATION OF MAMMALIA

Mammalia is a class of Phylum Chordate. Mammalian classification has been through several iterations since Carl Linnaeus initially defined the class. No classification system is universally accepted; McKenna & Bell (1997) and Wilson & Reader (2005) provide useful recent compendiums.Many earlier ideas have been completely abandoned by Linnaeus and modern taxonomists, among these are the idea that bats are related to birds or that humans represent a group outside of other living things. Competing ideas about the relationships of mammal orders do persist and are currently in development. Most significantly in recent years, cladistic thinking has led to an effort to ensure that all taxonomic designations represent monophyleticgroups. The field has also seen a recent surge in interest and modification due to the results of molecular phylogenetics.

George Gaylord Simpson's classic "Principles of Classification and a Classification of Mammals" (Simpson, 1945) taxonomy text laid out a systematics of mammal origins and relationships that was universally taught until the end of the 20th century

Since Simpson's 1945 classification, the paleontological record has been recalibrated, and the intervening years have seen much debate and progress concerning the theoretical underpinnings of systematization itself, partly through the new concept of cladistics. Though field work gradually made Simpson's classification outdated, it remained the closest thing to an official classification of mammals. See list of placental mammals and list of monotremes and marsupials for more detailed information on mammal genera and species.

Subclass 1: Prototheria

(Gr., protos, first + therios, beast)

Primitive, reptile-like, oviparous or egg laying animals.

1) Order 1 Monotremata
    - Family Tachyglossidae (Echidnas) &Family Ornithorhynchidae (Platypuses)

Subclass: 2: Theria

Infraclass Metatheria (marsupials and their nearest ancestors)

2) Order Didelphimorphia
    a) Family Didelphidae (opossums, etc.)
3) Order Paucituberculata
    a) Family Caenolestidae (shrew opossums)
4) Order Microbiotheria
    a) Family Microbiotheriidae (monito del montes)
5) Order Dasyuromorphia (most carnivorous marsupials)
    a) Family Thylacinidae (Tasmanian tigers), Family Myrmecobiidae (numbats)
    b) Family Dasyuridae (Tasmanian devils, quolls, dunnarts, planigale, etc.)
6) Order Peramelemorphia (bandicoots, bilbies, etc.)
    a) Family Peramelidae&Family Peroryctidae
7) Order Notoryctemorphia (marsupial moles)
    a) Family Notoryctidae
8) Order Diprotodontia
    a) Family Phascolarctidae (koalas), Family Vombatidae (wombats)

Fig.10.2 Example of Prototheria

b) Family Phalangeridae (brushtail possums and cuscuses)

Infraclass Eutheria

9) Order Xenarthra
   a) Family Bradypodidae, Family: Megalonychidae, Family: Dasypodidae
   b) Family: Myrmecophagidae

10) Order Insectivora
   a) Family Solenodontidae, Family Nesophontidae
   b) Family Tenrecidae, Family Chrysochloridae
   c) Family Erinaceidae, Family Soricidae
   d) Family Talpidae

Fig 10.3 Example of Eutheria

11) Order Scandentia
    a) Family: Tupaiidae
12) Order Dermoptera
    a) Family: Cynocephalidae
13) Order Chiroptera
    a) Family :Pteropodidae, Family: Emballonuridae, Family: Craseonycteridae, Family: Rhinopomatidae, Family: Nycteridae, Family: Megadermatidae, Family: Rhinolophidae
14) Order Primates
    a) Family: Daubentoniidae, Family: Lemuridae , Family: Lepilemuridae
    b) Family: Galagidae, Family: Lorisidae, Family: Cheirogaleidae,

15) Order Carnivora
    a) Family: Felidae, Family: Viverridae, Family: Herpestidae
    b) Family: Hyaenidae, Family: Canidae, Family: Ursidae
16) Cetacea
    a) Family :Balaenopteridae, Family: Eschrichtiidae, Family: Balaenidae
    b) Family: Neobalaenidae, Family: Physeteridae, Family: Ziphiidae
17) Order Sirenia
    a) Family: Dugongidae,
    b) Family :Trichechidae

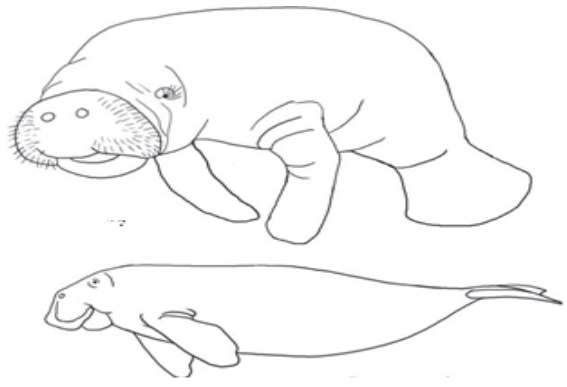

Fig 10.4Manatee vs Dugong

18) Order Proboscidea
    a) Family Elephantidae

19) Order Perissodactyla
    a) Family Equidae,
       Family Tapiridae,
       Family Rhinocerotidae

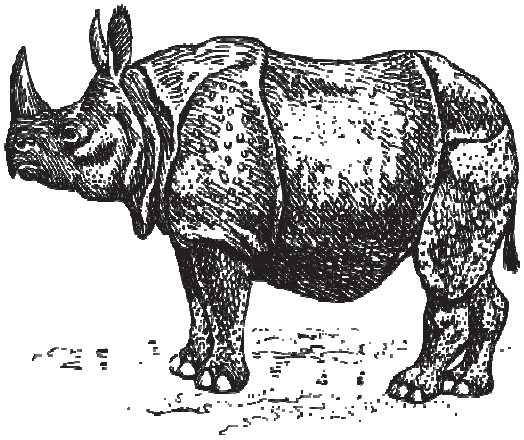

Fig 10.5

20) Order Hyracoidea
    a) Family Procaviidae

21) Order Tubulidentata
    a) Family Orycteropodidae

22) Order Artiodactyla
    a) Family Suidae, Family Tayassuidae, Family Hippopotamidae
    b) Family Camelidae, Family Tragulidae, Family Giraffidae

23) Order Pholidota
    a) Family Manidae

24) Order Rodentia
    a) Family Aplodontiidae, Family Sciuridae, Family Castoridae
    b) Family Geomyidae, Family Heteromyidae, Family Dipodidae
    c) Family Muridae, Family Anomaluridae, Family Pedetidae
    d) Family Ctenodactylidae, Family Myoxidae, Family Bathyergidae

25) Order Lagomorpha
    a) Family Ochotonidae

26) Order Macroscelidea

a) Family Macroscelididae

Subclass Prototheria

27) Order Platypoda: platypuses

a) Family Ornithorhynchidae: platypuses

28) Order Tachyglossa: echidnas (spiny anteaters)

a) Family Tachyglossidae: echidnas

Subclass Theriiformes

a) Infraclass -Allotheria

29) Order Multituberculata: multituberculates

a) Family Plagiaulacidae

30) Super legion Kuehneotheria

a) Family Kuehneotheriidae

b) Family Woutersiidae

31) Super legion Trechnotheria

a) Legion Symmetrodonta

30. Order Amphidontoidea

a) FamilyAmphidontidae

31. Order Spalacotherioidea

a) FamilyTinodontidae

32) Legion Cladotheria

a) Sublegion †Dryolestoidea

32. Order Dryolestida

a) Family Austrotriconodontidae

b) Family Dryolestidae

33. Order Amphitheriida

a) Family Amphitheriidae

33) Sublegion Zatheria

a) Family Arguitheriidae

34) InfralegionPeramura

a) Family Peramuridae

35) Infralegion Tribosphenida

a) Family Necrolestidae

SupercohortAegialodontia

a) Family Aegialodontidae

Supercohort Theria: therian mammals

b) Family Pappotheriidae

c) Family Plicatodontidae

Order Deltatheroida

a) Family Deltatheridiidae

b) Family Deltatheroididae

Order Asiadelphia

a) Family Asiatheriidae

Superorder Microbiotheria

a) Family Microbiotheriidae: monito del monte

Superorder Eometatheria

43) Order Yalkaparidontia

a) Family Yalkaparidontidae

44) Order Notoryctemorphia: marsupial moles

a) Family Notoryctidae: marsupial moles

45) Order Peramelia: bandicoots

a) Family Peramelidae

b) Family Peroryctidae

46) Order Diprotodontia

a) Family †Palorchestidae

47) Order Didelphimorphia: opossums

a) Family Didelphidae: opossums

48) Order Paucituberculata

a) Family Sternbergiidae

49) Order Sparassodonta

a) Family Mayulestidae

50) Order Cingulata: armadillos and relatives
    a) Family Dasypodidae: armadillos
51) Order Pilosa: anteaters, sloths, and relatives
    a) Family Entelopidae
    b) Family Myrmecophagidae: giant anteaters and relatives

Magnorder Epitheria: epitheres

52) Superorder Leptictida
    a) Family Gypsonictopidae
    b) Family Kulbeckiidae
53) Superorder Preptotheria
54) Grandorder Anagalida
    a) Family Zambdalestidae
55) Mirorder Macroscelidea: elephant shrews
    a) Family Macroscelididae: elephant shrews

Mirorder Duplicidentata

56) Order Mimotonida
    a) Family Mimotonidae
57) Order Lagomorpha
    a) Family Ochotonidae: pikas
58) Mirorder Simplicidentata
58) Order Mixodontia
    a) Family Eurymylidae
59) Order Rodentia: rodents
    a) Family Alagomyidae. Family Thryonomyidae: cane rats

Grandorder Ferae

60) Order Cimolesta - pangolins and relatives
    a) Family Palaeoryctidae, Family †Cimolestidae, Family †Apatemyidae
61) Order Creodonta: creodonts
    a) Family Hyaenodontidae, Family †Oxyaenidae
62) Order Carnivora

a) Family Viverravidae, Family †Nimravidae, Family Procyonidae: ringtails, olingos, kinkajou, raccoons, coatis, red panda

63) Order Chrysochloridea

a) Family Chrysochloridae: golden moles

64) Order Erinaceomorpha

a) Family Sespedectidae, Family Amphilemuridae

65) Order Soricomorpha

a) Family †Otlestidae, Family Geolabididae

66) Order Chiroptera: bats

a) Family Pteropodidae: flying foxes, Family Archaeonycteridae

67) Order Primates: primates

a) Family †Purgatoriidae, Family Microsyopidae

68) Order Scandentia

a) Family Tupaiidae: tree shrew

Grandorder Ungulata: ungulates

69) Order Tubulidentata

a) Family Orycteropodidae: aardvark

70) Order Dinocerata

a) Family Uintatheriidae

Mirorder Eparctocyona

71) Order Procreodi

a) Family Oxyclaenidae, Family †Arctocyonidae

72) Order Condylarthra

73) Order Arctostylopida

a) Family Arctostylopidae

74) Order Cete: whales and relatives

a) Family Triisodontidae, Family Mesonychidae: mesonychids

75) Order Artiodactyla: even-toed ungulates

a) Family Raoellidae, Family Hippopotamidae: hippos

76) Order Litopterna

a) Family Protolipternidae, Family Macraucheniidae

77) Order Notoungulata: notoungulates
    a) Family Henricosborniidae, Family Notostylopidae
78) Order Astrapotheria
    a) Family Eoastrapostylopidae, Family Trigonostylopidae
79) Order Xenungulata
    a) Family Carodniidae
80) Order Pyrotheria
    a) Family Pyrotheriidae

Mirorder Altungulata

81) Order Perissodactyla: odd-toed ungulates
    a) Family Equidae: horses, Family Palaeotheriidae
82) Order Uranotheria: elephants, manatees, hyraxes, and relatives
    a) Family Pliohyracidae, Family Procaviidae: hyraxes

10.5 AFFINITIES OF PROTOTHERIA

a) The prototheria are described as primitive unfinished mammals by Romer.

b) The mammary glands of prototheria are modified sweat glands unlike the Eutheria. Teatless mammary glands are characteristic of prototheria.

c) Males possess functional mammary glands. The feeding of young with milk by father and mother (parents) 'is known as gynaecomastism.

d) Auditory pinna or external ear is absent.

e) The skull is without tympanic bulla and lacrimals. Vertebrae are without epiphyses.

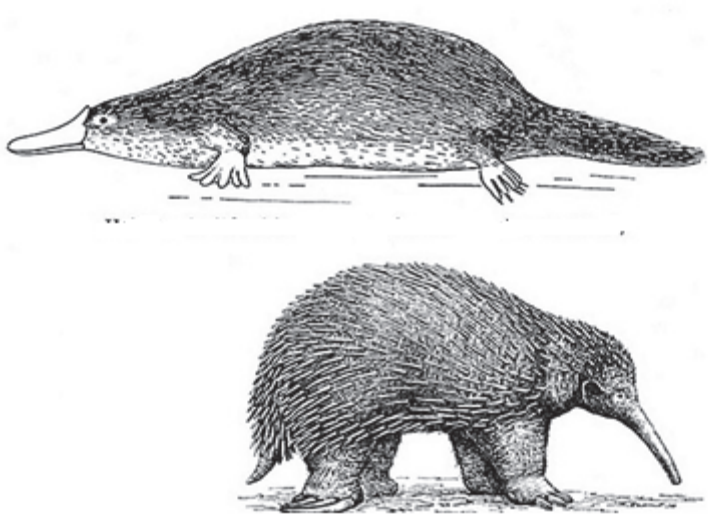

Fig 10.6 Monotremes vs Prototheria

f) Cervical vertebrae bear ribs. Ribs are single headed having capitulum only. A large coracoid with precoracoid and a T shaped interclavicle is present in pectoral girdle.

g) The pelvic girdle has a pair of epipubic bones which are absent in eutherians.

h) The body temperature is low and ranges from 25° C to 28°C. Hence, they are described as heterothermous mammals.

i) A cloaca is present into which ureters and urinogenital ducts open. Oviducts remain separate throughout the length and open into the cloaca.

j) Testes are abdominal. Penis helps to passout the sperms only.

k) There is no corpus callosum in the brain.

l) Teeth are present only in young ones; adults lack teeth, but a horny beak is present.

m) Females are oviparous laying large eggs with much amount of yolk (megalecithal).

n) Optic lobes are 4 in numbered.

o) Prototherians possess a number of reptilian characters in addition to the mammalian characters. So they form the bridge to fill the gap between reptiles and mammals, i.e they act as connecting link between Reptiles and Mammals.

Reptilian features of Monotremes

a) A large coracoid with precoracoid and T-shaped interclavicle in pectoral girdle.
b) Pelvic girdle is with epipubic bone.
c) Vertebrae are without epiphyses. Ribs are single headed.
d) Cloaca is present and testes are abdominal.
e) Lying of large eggs with abundant yolk.
f) Meroblastic cleavage is seen in the development.

Mammalian features of Monotremes

a) Hair is present all over the body.
b) Diaphragm is present.
c) Only left aortic arch is present.
d) Heart is 4 chambered.
e) Non-nucleated red blood corpuscles are seen in blood.
f) Mid brain shows four optic lobes.
g) Skin possesses mammary, sweat and sebaceous glands.
h) Three ear ossicles are present in the middle ear.
i) A single bone (dentary) is present in each half of the lower jaw.
j) A slightly coiled cochlea is present.

Prototheria includes only one living order Monotremata. It includes 3 living genera. These are found in ***Australia, Tasmania*** and ***New Guinea.***

a) Ornithorynchus or duck billed platypus:
It is distributed in Australia and Tasmania.

Fig.10.6 Macropus rufus

b**)** Echidna or Tachyglossus or spiny ant eater:
It is found in Tasmania and New Guinea.

c) Zaglossus or Proechidna:
It is found in New Guinea and resemblesTachyglossus.

10.6 AFFINITIES OF METATHERIANS

Metatheria or Marsupials are more advanced than the prototherians. They are all pouched mammals characterised by the presence of an integumentary brood pouch or ***marsupium*** in which the immature young ones are fed with the milk of the mother.

The marsupials occupy an intermediate position between the primitive mammals (monotremes) and the higher mammals (eutherians).

a) Marsupium or brood pouch is present in females. The mammary glands are present in the marsupium.

b) The marsupium is supported by epipubic (marsupial) bones.

c) The teeth are more in number. There are more than 3 incisors and more than 4 molars in each half of the jaw. Teeth are formed only once in life time. Hence, the dentition is called monophyodont dentition.

d) Corpus callosum is usually absent in the brain and Placenta is absent.

e) Although the anal and urinogenital apertures are separate and distinct, they are surrounded and controlled by a common sphincter muscle.

f) Testes are situated in scrotal sacs. The penis is present behind the scrotum and it is bifid.

g) The females have 2 oviducts, 2 uteri and 2 vaginae (didelphic condition) which separately open into urinogenital sinus.

h) The young ones are born naked and blind, but they posses clawed fore limbs by which they move into the brood pouch.

i) Fertilization and a major part of development are internal, but the young ones are born in immature state (mammary foetus).

j) Yolk sac placenta is present in marsupialia. True allantoic placenta is absent (except parameles). Yolk sac is large with villi.

k) Hind limbs are long in some animals like kangaroo.

l) The body temperature ranges from 36° C to 40° C.

Marsupials exhibit discontinuous distribution. Some marsupial's like ***kangaroos*** live in Australia and *oppossums* live in South America. Australia is described as the land of marsupials.

Eg: *Thylacinus* (Tasmanean wolf) is a carnivorous marsupial.

Notoryctus (Marsupial mole) is a burrowing form. *Phascolarctus* (koala bear) is an arboreal form. *Myrmecobius* (banded ant eater). *Parameles* is a marsupial bandicoot. *Macropus (Kangaroo)* is the largest marsupial. *Didelphls marsupialis* (American opposum).

10.7 AFFINITIES OF EUTHERIA

EUTHERIA OR PLACENTALIA- SALIENT FETURES

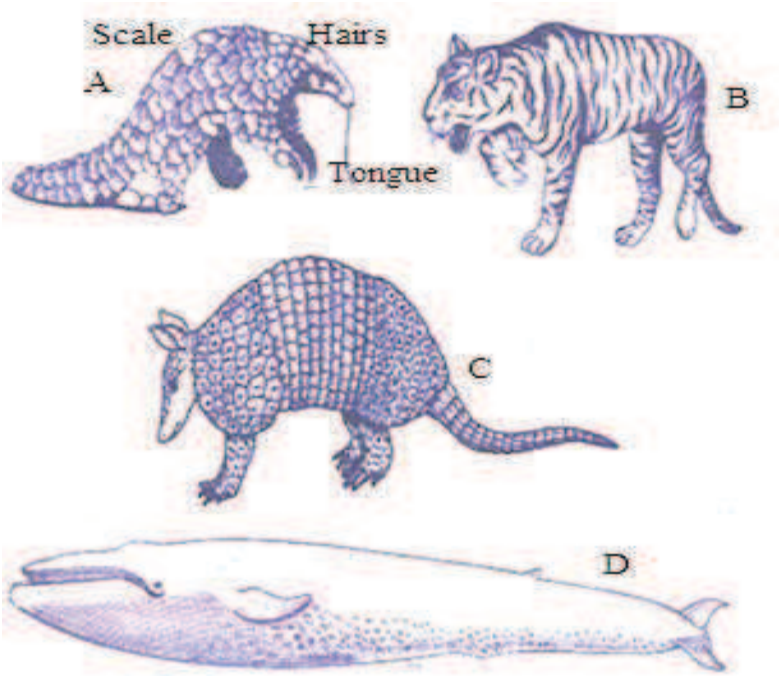

Fig 10.6 (A) Armadillo (B) Tiger (C) Pangolin (D) Blue Whale

a) These are highly evolved mammals with advanced organization.
b) Marsupium and marsupial bones are entirely absent.
c) Nourishment, respiration and excretion of young takes place through a complex *allantoic placenta.*

The young ones are born in relatively advanced state (miniature adults). Complete development takes place in the uterus only. Gestation period is generally long.

d) Testes are usually present in scrotal sacs. Penis is situated infront of the testes.
e) Vagina is single. Urinogenital passage and anus are separate
f) Cerebral hemispheres in brain have more convolutions.
   Corpus callosum is well developed. Eutherians are viviparous.
   Its distribution is world-wide.

Eg: *Rats, bats, rabbits, monkeys, cats, dogs, whales, horses, deers, pigs, elephants, man etc.*

10.8 STUDY OF RABBIT (ORYCTOLAGUS) AND DENTITION IN MAMMALS

Rabbits are small mammals in the family Leporidae of the order Lagomorpha, found in several parts of the world. There are eight different genera in the family classified as rabbits, including the European rabbit (*Oryctolaguscuniculus*), cottontail rabbits (genus *Sylvilagus*; 13 species), and the Amami rabbit (*Pentalagusfurnessi*, an endangered species on AmamiŌshima, Japan). There are many other species of rabbit, and these, along with pikas and hares, make up the order Lagomorpha. The male is called a *buck* and the female is a *doe*; a young rabbit is a *kitten* or *kit*.

Habitat of Rabbit:

Habitats of Rabits include meadows, woods, forests, grasslands, deserts and wetlands.Rabbits live in groups, and the best known species, the European rabbit, lives in underground burrows, or rabbit holes. A group of burrows is called a warren.

More than half the world's rabbit population resides in North America. They are also native to southwestern Europe, Southeast Asia,Sumatra, some islands of Japan, and in parts of Africa and South America. They are not naturally found in most of Eurasia, where a number of species of hares are present. Rabbits first entered South America relatively recently, as part of the Great American Interchange. Much of the continent has just one species of rabbit, the tapeti, while most of South America's southern cone is without rabbits.The European rabbit has been introduced to many places around the world.

Systematic Position

Phylum: Chordata

Subphylum: Vertebreta

Superclass: Tetrapoda

Class: Mammalia

Subclass: Theria

Order: Lagomorpha

Family: Leporidae

Type: Orchtolagcuniculus (Rabbit)

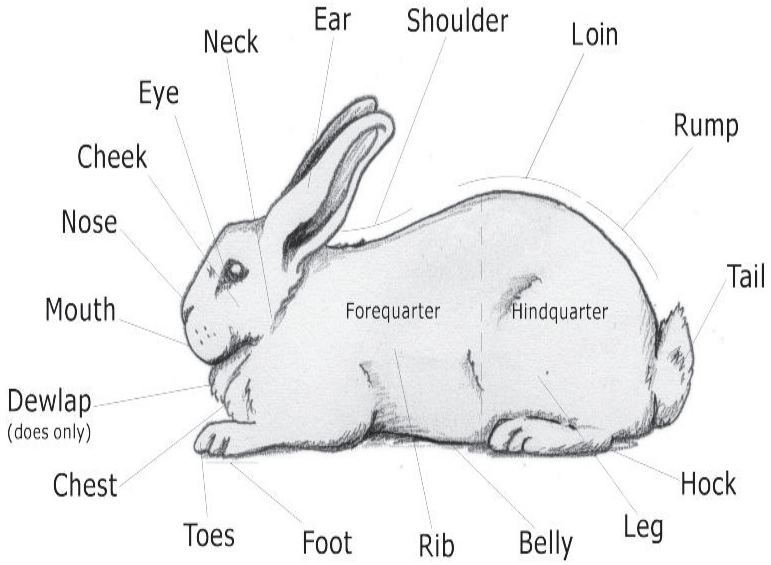

Fig 10.7 Rabbit

The rabbit is brown in colour. It is about 40 cm in long and it weighs 2 to 4 pounds. The entire body is covered with a soft uniform hairy coat or fur. The body is divisible into four parts namely- head, neck, trunk and tail.

The head is elongated and produced into a pointed snout. The mouth is a transverse slit on the ventral side of the snout. It is bounded by two lips- upper lip and lower lip. The upper lip has a cleft interest middle through which the incisor teeth are clearly visible. Such a lip is called harelip. The sides of the upper lip produce stiff long thick hairs called vibrissae or whiskers. They are tactile sensory organs.

The external nares or nostrils are a pair of large oval slits just above the mouth. Two lines are present on the sides of the sides of the head. They are protected an upper and a lower eyelids. A third eyelid called nictitating membrane is also present on the inner corner of the eye. The top of the head bears a pair of sound collecting lobes called ear pinnae. The pinna acts as a radar antenna. The basal part of each pinna has tubular ear opening called external auditory meatus.

This opening is closed below by a tympanic membrane or ear drum. The neck is short and permits the free movement of the head.

The Trunk is divisible into an anterior thorax and posterior abdomen. The ventral side of the abdomen is provided with 4 or 5 pair of teats or nipples. The teats are rudimentary in males. The anus is the present at the posterior end of the abdomen. On either side of the anus is a hairless depression called perineal pouches. The perineal scent glands lying inside open into these pouches. The secretions of these glands give the characteristics odour of the rabbit. In the male rabbit, the urinogenital aperture lies at the tip of penis (a muscular copulatory organ). The testes are lodged in two skin-bags called scrotal sacs which are present on either side of the penis. Instead in the female a vulva, the slit like aperture lies below the anus.

The trunk bears two pairs of limbs namely fore limbs and hind limbs. Each fore limb is divided into 3 parts namely a proximal upper branch (brachium), middle forearm (antebrachium) and a distal hand (manus). The hand is further divided into 3 parts namely wrist (carpus) and the palm (metacarpus) and the digits (fingers) with claws. The hind limb is also divided into thigh, the shank (crus) and the foot (pes). The foot is further sub-divided into an ankle (tarsus), a metatarsus and five toes with claws. The tail is hort and bushy and is located at the posterior end of the trunk.growing mass of cells. Cells of the outer layer of dermal papilla.

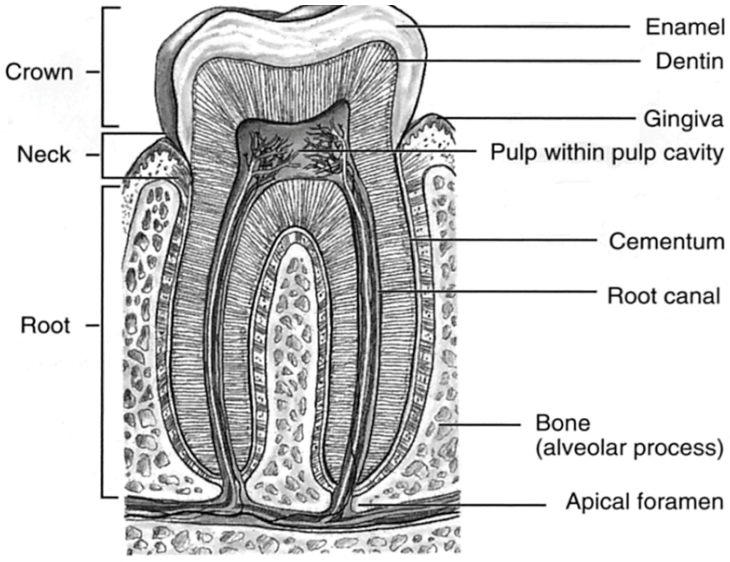

Fig.10.8 Dental structure in Rabbit

DEVLOPMENT OF TOOTH:

Teeth develop over the jaw bone where certain malpighian cells start actively multiplying forming a mass of cells called dental lamina or enamel organ. A dental papilla made of group of dermal cells appears below the dental lamina that supplies nourishment to the arrange themselves in a row and get differentiated into odontoblast cells**.** Epidermal cells of the dental lamina that cover the growing dentine are called ameloblasts. The tooth gradually grows outwards and eventually gets exposed by penetrating through the skin covering the jaw bone. The dental papilla inside the pulp cavity remains active along with its blood supply and nerve intact. This development of tooth is identical to the development of dermal scales in fishes. Hence shark teeth are also called modified placoid scales.

DENTITION IN MAMMALS:

Mammals as a rule possess heterodont ,diphyodont and thecodont dentition. However, some mammals lack teeth as given below in detail.

a) Among monotremes, the spiny anteater or echidna *(Tachyglossus* and *Zaglossus)* lacks teeth
b) Among the aquatic Cetacea baleen whales have no teeth, such as the blue whale, *Balaenopteramusculus* and, the whalebone whale. Among humans, and astonishingly, males in "Bhudas" tribe of Hyderabad Sindh in Pakistan
c) They are genetically so predisposed that they never grow teeth all their lives.

The Dental Formula:

Mammals have heterodont dentition having four types of teeth meant for different function in handling food in the oral cavity. Incisors in front are flat teeth designed for cutting food into pieces and the canines next to them are generally long and pointed spike-like used for tearing flesh by carnivore animals. Premolars and molars are located on the posterior side of the jaw, have flat surface with tubercles called cusps and are used for grinding food of plant origin. They are therefore well developed in herbivore animals. Number and arrangement of teeth in

mammals is specific in different groups of animals so much so that mammalian orders can be identified by their teeth and dental formula, which is written for one half of the upper and lower jaw as follows.

TYPES OF TEETH

Polyphyodont dentition involves replacement of teeth from time to time several times in lifetime so that jaws are never left without teeth. Lower vertebrates having loose attachment of teeth lose teeth while feeding and capturing prey and hence teeth must grow again to replace the lost ones.

Diphyodont dentition is a characteristic of mammals in which milk teeth appear in the young ones but as they grow and jaw becomes larger, milk teeth are replaced by larger permanent ones to fit in the larger jaw bone.

Monophyodont teeth appear only once in lifetime and if they fall they are never again replaced by the new ones. Toothless animals have this kind of teeth and marsupials retain their milk teeth.

Based on the type of attachment of teeth on the jaw bone the following three types are found in vertebrates:

Acrodont teeth are attached on the top surface of the jaw bone as in fish and amphibians. This type of attachment is not very strong and teeth are lost easily and are replaced by new ones.

Pleurodontteeth are attached on the inner side and uppper side of the jawbone that brings larger surface area of tooth in contact with jawbone and hence attachment is stronger, as in lizards and urodeles. But this attachment is also not as strong as thecodont.

Thecodont dentition is found in mammals in which root of the tooth is firmly fixed in a socket of the jawbone, making the attachment strongest in vertebrates. This is a peg and socket attachment with the help of cementum that surrounds the root portion of the tooth.

Based on the kinds of teeth found there are two types of dentition:

Homodont dentition is found in the majority of vertebrates such as fish, amphibia and reptiles in which all teeth are functionally and anatomically of the same type, although their size may be variable depending on the location. Sometimes functionally some teeth may be specialized as fangs of snakes.

Heterodont dentition occurs in mammals in which there are 4 functionally different types of teeth, namely, flat incisors for cutting, long and pointed canines for tearing flesh and large and broad premolars and molars with flat grinding surface. Molars have no counterparts in the milk teeth.

There are also some other type of teeth as follows:

Secodont teeth have sharp cutting edges that function like scissors to cut flesh as in some primates and in carnivores.

Bunodont teeth are small with smaller cusps or tubercles on the surface for handling soft diet as in man, monkeys, rodents etc.

Brachydont teeth are smaller and low crowned suitable for feeding on soft diet.

Hypsodont teeth possess larger crown that can resist wear and tear of feeding on tough and fibrous diet as in ungulates.

Selenodont teeth are found in horses and other ungulates in which silica deposit around cusps and in the depressions of the grinding surface.This makes the grinding surface of teeth harder to prevent wearing.

Lophodontteeth are found in elephants which feed on the roughest diet that any mammal can feed on.The ridges on the grinding surface are in the shape of rounded lophs and the depressions are filled with silica.

10.9 SUMMARY

Mammals are a well-known class of vertebrates, including many familiar domesticated species and pets, as well as our own species Homo sapiens. All mammals are warm-blooded, and all female mammals possess mammary glands (mammae), which are used to suckle the young with milk. Mammals are further distinguished by the possession of hair or fur, although this is limited to early developmental stages in the Cetacea (whales and dolphins). The vast majority of mammals give birth to live young, the exception being the egg-laying Monotremata (a small group of mammals including the duck-billed platypus and the echidnas or spiny anteaters). Monotremes are found exclusively in Australia and New Guinea. Mammals are found in a wide variety of habitats, including terrestrial, freshwater, and marine systems. They occur from the deserts to the dense forests, from the deep seas to the highest mountains, and from the tropics to the polar ice caps. Only one group of mammals, the Chiroptera (bats) is adapted to flight; other taxa such as flying squirrels or flying possums can glide effectively but are not capable of true flight.

10.10 GLOSAARY

1) Altricial - Mammals that are born in relatively undeveloped condition (eyes closed and with minimal fur) and require prolonged parental care—as opposed to precocial.
2) Alveolar - Of or pertaining to an alveolus (plural, alveoli), a small cavity or pit, as a socket for a tooth. Alveolar length of a tooth-row therefore denotes the length of the row of the teeth, taken from the posteriormost place where the back tooth emerges from the bone to the anteriormost point where the front tooth in the row emerges from the bone—the overall length of the bony sockets for the row of teeth.
3) Angular process - The projection at the posterior, ventral end of the mammalian dentary. See "dentary".

4) Annulation - A circular or ringlike formation, as of the dermal scales on the tail of a mammal where one ring of scales that extends entirely around the tail is succeeded, posteriorly, by other rings.
5) Arboreal - Inhabiting or frequenting trees—contrasted with fossorial, aquatic, and cursorial.
6) Auditory bulla (plural, auditory bullae) - A hollow, bony prominence of rounded form (in most mammals formed by the tympanic bone) partly enclosing structures of the middle and inner ear.

Ventral view of posterior skull of Nuttall's Cottontail Sylvilagus nuttallii, showing an auditory bulla (left); the wall of the right bulla has been broken, revealing the inside of the bulla.

7) Basal length - Distance on skull from the anteriormost inferior border of the foramen magnum to a line connecting the anteriormost parts of the premaxillary bones.
8) Basilar length - Distance on skull from the anteriormost inferior border of the foramen magnum to a line connecting the posteriormost margins of the alveoli of the first upper incisors.
9) Bead - A salient, rounded cordlike projecting ridge of bone, as in certain rodents where the superior border of the orbit is beaded.
10) Braincase - The part of the skull enclosing the brain.
11) Bunodont dentition - Referring to the cusp type of molars and/or premolars: cusps are low and rounded. The figure shows upper cheekteeth of a young domestic pig; some bunodont dentition, such as human teeth is simpler; others are more complex.
12) Calcar - In bats a process connected with the calcaneum (heel bone) and extending into the uropatagium near its edge, helping to support the uropatagium (the fold of skin that extends between the leg and tail). A keeled calcar is one with a definite flap of membrane posterior to the calcar extending beyond the general margin of the uropatagium.
13) Cancellous - Having a spongy or porous structure.

14) Canine - Of, pertaining to, or designating the tooth next to the incisors in mammals. Of or pertaining to dogs or to the family Canidae.
15) Carnivore - An animal that preys on other animals; an animal that eats the flesh of other animals; especially any mammal of the Order Carnivora.
16) Cheek-teeth - Teeth behind the canines.
17) Conch (plural, conchs) - The external ear of a mammal; sometimes the spelling is concha (plural, conchae); the origin of both spellings is conch or konch, originally a bivalve shell of a marine mollusk.
18) Condylar (condyloid, articular) process. On a mandible, the process ending in the articular condyle. See "dentary".

10.11 SELF-ASSESSMENT QUESTIONS

Q1. Give an account of distinguishing characters and outline classification of mammals?
Q2. Give the general characters and affinities of Prototheria?
Q3. Give the affinities of Metathiria?
Q4. Give the economic important of mammals?
Q5 Write short note in:
(a) Devlopment of tooth
(b) Prototheria

10.12 TERMINAL QUESTION ANSWERS

1) The burrow of Rabbit is called:
(a) Ware
(b) Form
(c) Barren
(d) Barre
2) The tail in Rabbit serves as:
(a) Balancing organs
(b) Sensory organ
(c) Decorative structure

(d) Hearing aid

3) In mammal hind limbs are absent in:
   (a) Cetaceans
   (b) Rodents
   (c) Marsupials
   (d) Chiropterans
4) Teeth in mammals are:
   (a) Thecodont, homodont, diphyodont
   (b) Thecodont ,hetrodont,diphyodont
   (c) Acrodont, homodont, monophyodont
   (d) Acrodont, homodont, polyphyodont
5) Typical prototheria character is:
   (a) Presence of cloaca
   (b) 4 chambers heart
   (c) Tarsal squr in males
   (d) Segmented sternum
6) Metatherian teeth are more than:
   (a) 32
   (b) 36
   (c) 4 0
   (d) 4.4
7) Milk dentition in mammals lack:
   (a) Molar
   (b) Premolars
   (c) Canines
   (d) Incisors

8) First teeth on maxillae:
   (a) Lower canines
   (b) Upper canines
   (c) Upper molar

(d) Lower premolar

9) Baleen is present in:
   (a) Lizards
   (b) Frogs
   (c) Whales
   (d) Elephants

10) Largest mammalian suborder:
   (a) Logomorpha
   (b) Rodenta
   (c) Cetacea
   (d) Sireni

Answers

1(a) 2 (a) 3 (a) 4(b) 5 (c) 6 (d) 7(a) 8 (b) 9 (c) 10(b)

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